Staff Report of the

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

REGIONAL WATER QUALITY CONTROL BOARD

CENTRAL VALLEY REGION

AGRICULTURAL DRAINAGE CONTRIBUTION TO WATER QUALITY IN THE GRASSLAND WATERSHED OF WESTERN MERCED COUNTY, CALIFORNIA: OCTOBER 1997 - SEPTEMBER 1998

(WATER YEAR 1998)

MAY 2000

State of California

California Environmental Protection Agency

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REPORT CONSIDERED AND APPROVED BY THE
CENTRAL VALLEY REGIONAL WATER QUALITY CONTROL BOARD
ON 28 APRIL 2000

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Many thanks to the staff and students of the Agricultural Unit without whose efforts during field sampling, quality control, and data processing, this report would not have been possible.

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EXECUTIVE SUMMARY

Since May 1985, the Central Valley Regional Water Quality Control Board has conducted a water quality monitoring program in the San Joaquin Valley of California to assess the impacts of agricultural subsurface drainage on wetland water supply channels in the Grassland Watershed. The Grassland Watershed is a 370,000-acre area, west of the San Joaquin River covering portions of Merced and Fresno counties between the Tulare Lake Basin and the Orestimba Creek alluvial fan. The watershed contains both farmed land, including a 97,000-acre area known as the Drainage Project Area (DPA), and approximately 100,000 acres of wetland habitat, including State and Federal wildlife refuges and private gun clubs. The watershed is tributary to the San Joaquin River, with Mud Slough (north) and Salt Slough serving as the main drainage arteries.

The time period covered by this report, 1 October 1997 through 30 September 1998 (Water Year 1998[1]), represents the second year of operation of the Grassland Bypass Project (GBP). The project began operation on 23 September 1996 and consolidated subsurface agricultural drainage, which historically flowed through wetland water supply channels, into a single channel, allowing the drainage to bypass approximately 90 miles of wetland water supply channels and Salt Slough. The drainage was redirected into the final 28 miles of the San Luis Drain for discharge into the lower nine miles of Mud Slough (north) and eventually into the San Joaquin River.

During Water Year 1998, water quality sampling was conducted at 12 sites within the Grassland Watershed and represented drainage from the DPA, internal wetland supply canals and overall discharge from the watershed. The primary constituents evaluated included electrical conductivity, boron and selenium, with more limited analyses of molybdenum, copper, chromium, lead, nickel, zinc, chloride and sulfate. Grab samples were collected on a weekly, monthly or quarterly schedule depending on the location and automated, composite samples were collected at selected sites to provide information on fluctuating concentrations and to provide a more complete data set for load calculations for salt, boron, and selenium.

The San Joaquin River Index is used to classify water year type in the river basin based on total runoff (SWRCB, 1995). Water Year 1998 was classified as a wet water year with periods of localized flooding occurring during February and March. Statewide, twice the normal precipitation occurred during January and over three times the normal occurred in February. During the February flooding, the Grassland Bypass could not handle the volume of drainage from the DPA and a portion of subsurface agricultural drainage was diverted through the wetland water supply channels and into Salt Slough between 3 and 28 February 1998. Flows in all the Grassland Watershed channels remained elevated through April 1998.

As noted during Water Year 1997, consolidating all subsurface agricultural drainage into the San Luis Drain for discharge into Mud Slough (north) markedly improved the water quality of internal channels and Salt Slough. During Water Year 1998, the improvements continued with electrical conductivity, boron and selenium concentrations in the internal canals and Salt Slough significantly lower than preproject conditions. A corresponding increase in constituent concentrations was noted in Mud Slough (north), reflecting discharge from the San Luis Drain. San Luis Drain discharge concentrations

[1] A Water Year covers the time period from 1 October through 30 September of the following year.

peaked at 6330 umhos/cm, 11 mg/L, and 134 ug/L for electrical conductivity, boron, and selenium, respectively, during Water Year 1998.

In October 1988, Central Valley Regional Board adopted water quality objectives for boron, molybdenum and selenium for Mud Slough (north) and Salt Slough and a selenium objective for water used to maintain wetland habitat (Resolution #88-195). The mean monthly boron objective (2.0 mg/L) depends on season and only applies from 15 March through 15 September, while the maximum objective applies year round. In May 1996, the Regional Board adopted revised selenium water quality objectives for the two sloughs and for wetland water supply channels, as well as a compliance time schedule for Mud Slough (north). The selenium compliance time schedule does not require compliance with the selenium objective until 1 October 2010. No water quality objectives have been adopted for the San Luis Drain.

During Water Year 1998, the boron objective (2.0 mg/L monthly mean) was only exceeded in Mud Slough (north) downstream of the San Luis Drain discharge. Upstream of the discharge, the concentrations approached 2.0 mg/L during March, April and May, but did not exceed the objective. The elevated concentrations may be due to a number of factors including localized elevated levels in groundwater seepage, releases from wetlands, and other surface drainage. Downstream of the discharge, the objective was exceeded continuously from March through September. No boron objective exceedances were observed in Salt Slough, during Water Year 1998.

During Water Year 1998, the selenium objectives were a 2 ug/L monthly mean for Salt Slough and wetland water supply channels and a 5 ug/L, 4-day average for Mud Slough (north) that is subject to a compliance time schedule. The objective was exceeded in Salt Slough in February 1998. The exceedance corresponds to the time period when excess subsurface agricultural drainage mixed with flood water was being directly diverted into wetland channels. Exceedances occurred sporadically in the wetland water supply channels, with the majority between February, March, and April. Exceedances in the supply channels may be due to a number of factors including elevated selenium levels in supply water, releases from the DPA (both in response to flood events and seepage from gates and canals), inflows from other agricultural subsurface drainage sources, and local sources such as groundwater seepage and surface return flows. Direct diversions into the channels and seepage from gates occurred until the gates were sealed on 21 April 1998. Additional selenium sources are being investigated by Regional Board staff and local water agencies. Results of such investigations will be published separately.

Selenium concentrations in Mud Slough (north) above the drainage discharge remained below 5 ug/L, while monthly mean concentrations in the slough downstream of the drainage discharge remained above 5 ug/L, peaking at 67.3 ug/L during May. Mud Slough (north) is subject to a compliance time schedule.

Molybdenum concentrations were measured at four sites during Water Year 1998, Mud Slough (north) both upstream and downstream of the San Luis Drain discharge, the San Luis Drain Discharge itself, and Salt Slough. The molybdenum objective (19 ug/L) was only exceeded downstream of the drainage discharge. The exceedances occurred during April and May. Monthly mean molybdenum concentrations in the drainage discharge ranged from 16 ug/L to 48 ug/L. No molybdenum objectives apply to the San Luis Drain.

Salt, boron, and selenium loads for the GBP and the Grassland Watershed were estimated based on the flow weighted monthly average of available water quality data for Water Year 1998. This was the second year of operation of the Grassland Bypass Project (GBP). Prior to Water Year 1997, discharge and load from the Drainage Project Area (DPA) was estimated by summing the discharge and load in several channels within the Grassland Watershed. Starting in Water Year 1997, all drainage from the DPA was diverted into the Grassland Bypass and the San Luis Drain as part of the GBP. Discharge and loads from the DPA for 1998 are therefore based on discharges and loads from the GBP.

High rainfall in February resulted in extremely high discharge from the Grassland Watershed in February and March as well as continued high discharges from the DPA from February through September. Monthly salt and boron loads peaked for both areas in March. Loads of salt and boron from the DPA remained elevated through the rest of the Water Year whereas loads from the rest of the Grassland Watershed decreased after March. Loads from the DPA therefore accounted for a disproportionately larger portion of the total load of salt and boron during the summer and fall. As usual, the DPA accounted for most of the selenium load (9,110 pounds) in the Grassland Watershed, accounting for just less than 95 percent of the total annual load of 9,630 pounds in the Grassland Watershed.

Annual flow from the Grassland Watershed was the highest on record for the thirteen-year period from 1986 to 1998. There were several prior years with higher annual flow from the DPA. Annual salt load from the Grassland Watershed were also the highest on record for the thirteen-year period. There were higher salt loads discharged from the DPA in several earlier years. Water Year 1998 boron loads from both the DPA and the Grassland Watershed were the highest on record for the thirteen-year period. Only Water Year 1995 had higher selenium loads discharged from the Grassland Watershed. In contrast, more selenium was discharged from the DPA in several wet years prior to 1998.

High annual discharge and loads of salt, boron, and selenium in the Grassland Watershed are attributable to high rainfall in the watershed. Trends of discharge and loads from the DPA are affected not only by hydrology, but also changes in management of the DPA over the last few years. With the advent of the GBP and use of the San Luis Drain to route agricultural drainage from the DPA to Mud Slough (north), new management practices have been employed by the Grassland Area Farmers (GAF's). The GAF's have greatly restricted the quantity of tailwater that is commingled with subsurface tile drainage. They have also used selective recycling and blending of tile drainage with agricultural supply water and other water conservation and drainage reduction methods to reduce peak selenium loads. Water conservation and tailwater reduction have likely contributed to the overall reduction in drainage volume discharged from the DPA in recent wet years relative to prior wet years. Reduction in drainage volume from the DPA has resulted in reduction of salt load, relative to other wet years. Recycling of tile drainage has likely contributed to significantly lower annual selenium loads discharged from the DPA relative to prior wet years.

INTRODUCTION

The Agricultural Unit of the Central Valley Regional Water Quality Control Board (Regional Board) initiated a water quality monitoring program in May 1985 to evaluate the effects of subsurface agricultural drainage on the water quality of canals, drains, and sloughs in the Grassland Watershed in western Merced County. The Grassland Watershed is located west of the San Joaquin River between the Tulare Lake Basin and the Orestimba Creek alluvial fan. The purpose of this monitoring program was to compile an on-going database of selected inorganic constituents found in agricultural drains that discharge to and flow through wildlife areas before entering the San Joaquin River. This database has been and continues to be used to develop and evaluate water quality control programs addressing agricultural drainage in the San Joaquin River Basin.

This report contains laboratory results and a summary of water quality analyses for all constituents measured as part of the program during Water Year 1998 (October 1997 through September 1998).[2] Water Year 1998 (WY98) represents conditions during the second year of operation of the Grassland Bypass Channel Project, which began operation on 23 September 1996. The project consolidated subsurface agricultural drainage, which historically flowed through wetland water supply channels, into a single channel, allowing the drainage to bypass approximately 90 miles of wetland water supply channels. Water quality information collected as part of this multiagency project is available on the U.S. Bureau of Reclamation's Grassland Bypass Project web page at:

www.mp.usbr.gov/mp150/grassland/HomePage/Homepage.html

This report presents the water quality data collected by the Regional Board and compares salinity (measured as electrical conductivity), boron and selenium water quality at selected sites with respect to hydrology, change in water management, and applicable water quality objectives.

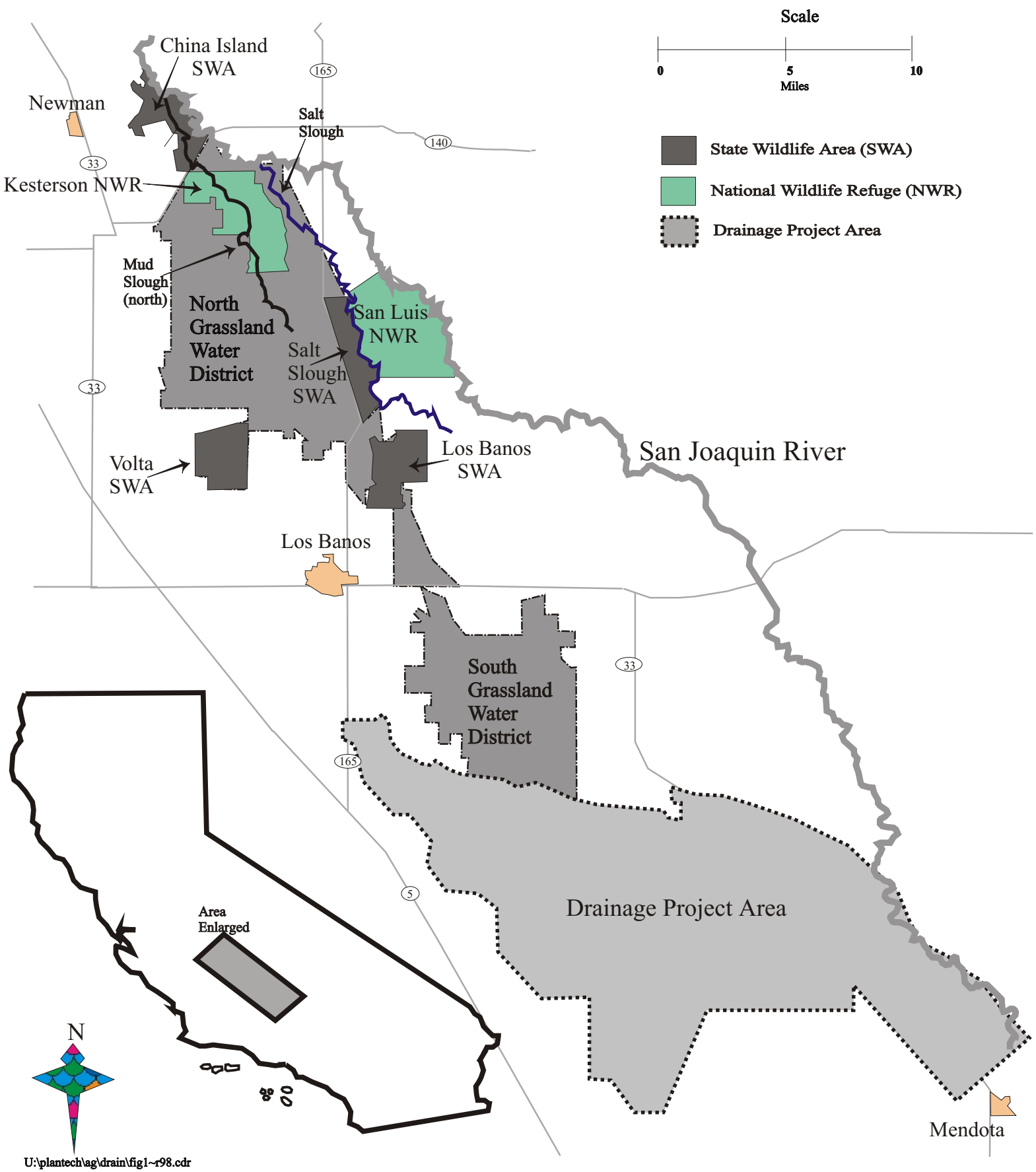
Water quality data collected during the previous years of study can be found in both a summary report presenting salinity, boron, and selenium information from May 1985 through September 1996 (Steensen et al., 1998) and in a series of annual reports presenting all water quality information collected through September 1997 (James et al., 1988; Chilcott et al., 1989; Westcot et al., 1990, 1991, and 1992; Karkoski and Tucker, 1993; Vargas et al., 1995; Chilcott et al., 1995; Steensen et al., 1996; and Chilcott et al., 1998).

STUDY AREA

The study area consists of the Grassland Watershed located west of the San Joaquin River between the towns of Newman and Mendota, in the San Joaquin River Basin in California. The watershed encompasses approximately 370,000 acres and includes the northern and southern divisions of Grassland Water District (GWD), and farmlands adjacent to the district. The watershed contains a 97,000-acre area known as the Drainage Project Area (DPA), and approximately 100,000 acres of wetland habitat, including State and Federal wildlife refuges and private gun clubs (Figure 1).

[2] A water year lasts from October 1st of one year through September 30th of the following year.

Figure 1. Grassland Watershed, State and Federal Wildlife Refuges, and Drainage Project Area



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Prior to October 1996, agricultural lands east, west, and south of the GWD discharged subsurface agricultural drainage water (tile drainage) and surface runoff (irrigation tailwater) through the GWD. Subsurface drainage from this area often contains high concentrations of salt, selenium and other trace elements. This regional drainage flowed north through the GWD, carried by a network of canals that could divert water in several possible ways before discharging into Mud Slough (north) or Salt Slough. These two sloughs are tributary to the San Joaquin River and serve as the primary drainage outlets for the Grassland Watershed.

After October 1996, all subsurface agricultural drainage from the DPA was rerouted into the Grassland Bypass which discharges into the final 28 miles of the San Luis Drain. The consolidated subsurface drainage is then released into Mud Slough (north), nine miles upstream of its confluence with the San Joaquin River. Consolidating the subsurface drainage removed the primary source of selenium in approximately 90 miles of canals which can supply water to wetland habitat. Reducing selenium in these water bodies was a primary goal of the project, since elevated concentrations of selenium have been documented to impact waterfowl (Skorupa, 1998).

A small number of subsurface agricultural drainage systems to the east and west of the Grassland Water District continue to discharge into local drainage courses that enter the wetland area. Evaluation of these discharges is being conducted by local water agencies and Regional Board staff with findings to be drafted in a separate report (Chilcott, 1999).

SAMPLING PROGRAM

Prior to October 1996, water quality sampling was conducted at inflow sites to, internal flow sites within the GWD, and four outflow sites from the Grassland Watershed. Inflow monitoring stations were located on drains that discharge into the GWD and are mainly situated at the southern end of the study area. Internal sites were located on canals within the GWD that carried or could carry subsurface tile drainage as it passes through, before discharging to the San Joaquin River. Outflow monitoring stations were located on water bodies which flow out of the Grassland Watershed.

Mud Slough (north) and Salt Slough are the primary tributaries to the San Joaquin River that drain the Grassland Watershed and are described in detail in previous reports (Pierson et al., 1989a and 1989b). Mud Slough (north) downstream of the San Luis Drain (MER542) and Salt Slough at Lander Avenue (MER531) are located near flow monitoring stations operated by the U.S. Geological Survey and are two principal stations in this monitoring program.

During Water Year 1997, the water quality monitoring program was altered to reflect the changes in drainage water management resulting from the use of the Grassland Bypass. With the consolidation of agricultural subsurface drainage, a majority of the inflow sites which historically contained the drainage, were eliminated from the sampling program. The remaining sites focused the monitoring program on providing data which could be used to evaluate the impact of the bypass. Key sites which were maintained and provide comparison to pre-bypass conditions include: Camp 13 Slough and Agatha Canal (inflow); Santa Fe and San Luis Canals at Henry Miller Road (internal); and Mud Slough (north) downstream of the San Luis Drain terminus and Salt Slough (outflow). In addition, three new sites were added to evaluate the discharge from the bypass itself: Mud Slough (north) upstream of the bypass discharge (MER536), discharge from the San Luis Drain (MER535), and inflow

Table 1. Water Quality Monitoring Sites in the Grassland Area for Water Year 1998

Map Index	RWQCB Site I.D.	Site Name	Site Type
I-4	MER506	Agatha Canal @ Mallard Road	Inflow
I-7	MER505	Camp 13 Slough	Inflow
T-1	MER510	CCID Main @ Russell Avenue	Inflow
T-5	MER519	Sante Fe Canal @ Henry Miller Road	Internal Flow
A	MER545	Santa Fe Canal @ weir	Internal Flow
T-7A	MER532	San Luis Canal @ Henry Miller Road	Internal Flow
B	MER563	San Luis Canal @ splits	Internal Flow
O-2	MER542	Mud Slough (N) @ San Luis Drain	Outflow
O-4	MER531	Salt Slough @ Lander Avenue	Outflow
SLD-1	MER562	Inflow to San Luis Drain @ Check 17	Internal Flow
SLD-2	MER535	San Luis Drain @ Terminus	Outflow
O-8	MER536	Mud Slough (N) Upstream of SLD	Internal Flow

CCID = Central California Irrigation District
Location map is in Appendix A.

from the Grassland Bypass to the San Luis Drain at Check 17 (MER562). Water Year 1998, continued the monitoring program begun during Water Year 1997 with three additions: the Santa Fe Canal and the San Luis Canal approximately one half mile upstream of Henry Miller Road, and the Central California Irrigation District (CCID) Main Canal at Russell Blvd. The additions were instigated in order to better identify sources of selenium reaching the monitoring sites. In total, water samples were collected at twelve sites during Water Year 1998 (Table 1).

SAMPLE COLLECTION METHODS

Two distinct types of water samples were collected for this program: grab samples and automated composite samples. Staff from the Panoche Water District collected grab samples from eight of the sites during Water Year 1998: the CCID Main Canal, Camp 13, Agatha Canal, Santa Fe Canal upstream of and at Henry Miller Road, San Luis Canal upstream of and at Henry Miller Road, and the Grassland Bypass inflow to the San Luis Drain. Staff from the Regional Board collected samples from the remaining sites. Field measurements for water temperature, electrical conductivity (EC), and pH were conducted at all sites monitored by Regional Board staff. Follow up EC measurements were made on all samples at the Regional Board office laboratory: within 24 hours for samples collected by Regional Board staff and within 24 hours of receipt of samples from Panoche Water District staff. The types of samples, methods for collection and quality control and assurance are discussed below.

Grab Samples

During Water Year 1998, grab samples were collected on either a weekly, monthly or quarterly basis depending on site and the constituent to be analyzed (Table 2). Analyses for EC, total boron, and total selenium were conducted on all samples. Selected sites were also monitored for molybdenum, copper, chromium, nickel, lead, and zinc on a monthly or quarterly basis. Samples were also analyzed for dissolved selenium and total suspended solids at both the inflow to and outflow from the San Luis Drain.

Table 2. Water Year 1998 Monitoring Sites, Sampling Frequencies, and Parameters Measured: Grasslands Bypass Project

Site Description	Constituents									Diss.	Auto-
	Temp	pH	EC	Se	Mo	TE's	B	Part Min	TSS	Se	Samplers
CCID Main @ Russell Ave.			W	W			W				
Camp 13 Slough @ Gauge Station			W	W			W				
Agatha Canal @ Mallard Road			W	W			W				
Santa Fe Canal @ Henry Miller Road			W	W			W				
San Luis Canal @ Henry Miller Road			W	W			W				
Mud Slough (north) Upstream of San Luis Drain	W	W	W	W	M	Q	W	Q			
Inflow at San Luis Drain: Check 17			W	W			W		W	W	
San Luis Drain @ Terminus	W	W	W	W	M	Q	W	Q	W	W	a
Mud Slough (north) Downstream of San Luis Drain	W	W	W	W	M	Q	W	Q			
Salt Slough @ Lander Ave.	W	W	W	W	M	Q	W	Q			

W = weekly
M = monthly
Q = quarterly (October, January, April, and July)
a = daily composite sample for Se and B

TE's: Trace Elements (chromium, copper, lead, nickel, zinc)
Part Min = B, Cl, SO4, and Hardness
TSS=total suspended solids

Grab samples were collected in polyethylene bottles, usually within six feet of the bank. Depth integrated samples were collected mid-channel at the inflow to the San Luis Drain, outflow from the San Luis Drain, and at Mud Slough (north) downstream of the San Luis Drain discharge. All sample bottles were rinsed with deionized water before use. All bottles were also rinsed three times with the water to be sampled prior to sample collection. All samples were kept on ice after collection and until processing. Selenium, boron, and trace element samples were preserved by lowering the pH to less than 2 within 24 hours of collection, using reagent grade nitric acid. Mineral and total suspended sediment samples were kept on ice until submittal to the laboratory for analysis.

Composite Automated Samples

In addition to grab samples, daily composite sampling was conducted at the San Luis Drain discharge through the use of automated Sigma sampling devices. During Water Year 1998, two autosamplers (one strictly backup) were operated at the San Luis Drain site. Each daily composite was made up of six 85 ml collections pulled at four hour intervals for a total sample volume of 510 ml. During the year, the autosamplers were serviced every two weeks. The daily samples were analyzed for EC, boron and selenium. Quality control and assurance methods for the autosamplers are discussed below.

QUALITY CONTROL AND QUALITY ASSURANCE

Potential contamination from the reagent grade nitric acid used to control pH was evaluated by submitting a deionized water matrix preserved with the normal amount of acid used (1 ml nitric acid per 500 ml of sample), to the contract laboratories at monthly intervals to be analyzed for the trace elements of concern. All reported recoveries for these acid check samples were below the analytical detection limit.

Field and handling contamination was evaluated by submitting a travel blank on a monthly basis. The travel blank consisted of a sample of deionized (DI) water which was collected at the Regional Board laboratory, traveled through the sampling run, and was then processed with the sample set. All results for travel blanks fell below the analytical detection limits for the elements of concern.

Table 3. Quality Assurance Tolerance Guidelines Used in the Regional Water Quality Control Board Agricultural Drainage Monitoring Program.

Constituent	Recovery Range at Low Levels (ug/L)*	Acceptable Split/Spike Recovery Range
Copper	1-20 ± 5	>20 70-130%
Chromium	1-20 ± 5	>20 70-130%
Lead	5-25 ± 8	>25 60-140%
Molybdenum	1-10 ± 2	>10 90-110%
Nickel	5-25 ± 6	>25 65-135%
Selenium	0.4-10 ± 0.8	>10 90-110%
Zinc	1-20 ± 6	>20 70-130%
Boron	50	85-115%
Chloride	5000	85-115%

* For certain constituents, recovery is expressed as an absolute value rather than a percentage at low levels. For example, if the result of copper analysis for a particular sample is 10 ug/L, a split analysis must fall between 5 ug/L and 15 ug/L. If the sample is greater than 20 ug/L, recovery is expressed as a percent and must be between 70 and 130%. If a recovery range is not shown at low levels, the detection limit is given.

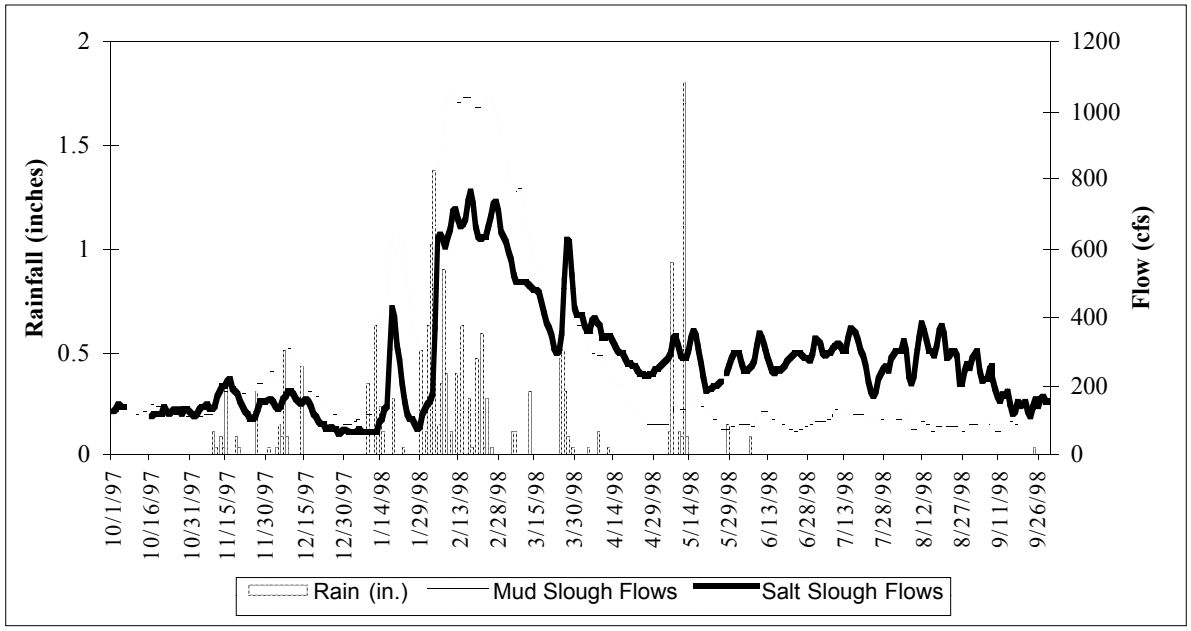
Additional quality control and quality assurance was conducted using blind split and spiked samples. Blind split samples were collected at a ten percent frequency for each sampling event by collecting the sample in a container double the normal sample volume and splitting that sample into two equal amounts for submittal to the analyzing laboratory. On a monthly basis, half of the blind split samples were spiked with known concentrations of constituents to be analyzed. Comparing the spiked splits to the background splits provided information on analytical accuracy. Comparing data from nonspiked splits provided information on analytical precision.

To evaluate the potential for contamination and evapo-concentration in samples collected using autosamplers, a series of special checks were developed. First, whenever the sampler was serviced, a deionized blank sample, without a cap, was left in the collection base to be collected on the next servicing and analyzed for potential contamination. Second, during each servicing, replicate "grab" samples were collected through the autosampler mechanism, one was left in the sampler to be collected at the next servicing and the other was processed for immediate analyses. Final results of the two grabs were evaluated to determine concentration or dilution potentials.

During Water Year 1998, samples for dissolved selenium were collected at two locations (MER535 and MER562). These samples required field filtration through an 0.45 mm cartridge system. To prevent and evaluate potential contamination, the equipment was soaked in a two percent nitric acid solution between usages, and rinsed three times in DI water. The new filters were conditioned at the time of sampling by allowing the first 10 ml of water passed through to be discarded before the remaining sample was collected. Approximately quarterly, filter blanks were collected using the Regional Board laboratory DI water and processing it through the standard equipment used in the field.

Only data from sample sets whose blind QA/QC met specifications outlined in Table 3 have been included in this report.

Figure 2. Flows in Mud Slough (north) and Salt Slough as Compared to Rainfall at CIMIS Station #124 @ Kesterson: Water Year 1998



RAINFALL AND DISCHARGE PATTERNS

The San Joaquin River Index, as described in the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (SWRCB, 1995) is used to classify water year type in the river basin based on runoff. The 60-20-20 Index includes one "wet" classification, two "normal" classifications (above and below normal), and two "dry" classifications (dry and critical), for a total of five water year types. Water year 1998 was classified as "wet" based on runoff exceeding 3.8 million acre feet.

Mud Slough (north) and Salt Slough are the main water bodies that drain the Grassland Watershed. Figure 2 compares daily flows in both sloughs to the monthly rainfall at CIMIS[3] station #124 located at Kesterson National Wildlife Refuge (NWR), for Water Year 1998. Flows peaked during February in response to severe winter storms and flooding. Statewide, twice the normal precipitation occurred during January and over three times the normal occurred in February (DWR, 1998). Rainfall totals reached a record high of 7.7 inches during the month of February in Kesterson NWR. The elevated flows continued into April 1998. The peaks and sustained highs which do not correspond to rainfall events are generally a result of groundwater, wetland discharges, and surface irrigation return flows.

The high rainfall during February 1998, resulted in localized flooding which in turn resulted in the diversion of commingled agricultural subsurface and storm drainage flows from the DPA into water bodies flowing through the Grassland Watershed. Diversions into Camp 13 Slough and the Agatha Canal occurred between 3 and 28 February 1998. Flows into these two water bodies may be diverted in

[3] CIMIS stands for California Irrigation Management Information System. Stations are located throughout California and maintained by the California Department of Water Resources.

a number of directions before final discharge through either Mud Slough (north) or Salt Slough. [An extensive summary of the hydrology of the Grassland Watershed can be found in Steensen, *et al*., (1998).] Although direct diversion into the Camp 13 and the Agatha ceased by 28 February 1998, some seepage of the commingled drainage and stormwater continued to occur until 21 April 1998. By 21 April, all inlets from the DPA to Camp 13 Slough had been sealed off (GAF memo, 27 August 1998).

RESULTS

Water Year 1998

Grab sample water quality results for minerals and trace elements, as well as EC, pH, and temperature at time of sampling, are listed by site in Appendices A and B. Appendix A includes grab data for sites sampled during Water Year 1998 and Appendix B lists all information collected using automated Sigma samplers at the San Luis Drain discharge. The number of sampling events and the ranges, mean and median values for each measured constituent at each site are shown in these appendices. Results are presented below. Data for Water Year 1998 has been divided into results for the San Luis Drain and Mud Slough (north), and wetland water supply channels and Salt Slough. Also presented is data from the autosamplers which collected daily composites. Tables 4 lists the median constituent concentrations for all water bodies monitored in the Grassland Watershed during Water Year 1998. Table 5 summarizes annual minimum, mean and maximum EC, boron and selenium concentrations at locations sampled in the watershed during Water Year 1998 and compares those values to the average range in concentration during the previous 12 water years of record. The previous 12 years of record contained seven critically dry years and five wet years as determined using the San Joaquin River Index (SWRCB, 1995). The summary information for the previous data record is presented in full and has also been separated into critically dry years and wet years. Additional information on water quality parameters measured during this program is contained in Appendix A.

Table 4. Median Constituent Concentrations for Waterways within the Grassland Watershed: Water Year 1998.

Type	Station	EC (umhos/cm)	B	Cl	SO4	Se	Mo	Cr	Cu	Ni	Pb	Zn	Hardness mg/L
			mg/L			ug/L							
I	Agatha Canal	539	0.44	—	—	1.2	—	—	—	—	—	—	—
I	Camp 13	673	0.65	—	—	1.6	—	—	—	—	—	—	—
T	CCID Main Canal	260	0.17	—	—	1.1	—	—	—	—	—	—	—
T	Santa Fe Canal @ Henry Miller Rd.	970	1.1	—	—	1.5	—	—	—	—	—	—	—
T	San Luis Canal @ Henry Miller Rd	1000	1.4	—	—	1.8	—	—	—	—	—	—	—
O	Salt Slough @ Lander	1380	0.73	175	150	0.9	8	3.5	4.1	6.8	<5	—	240
D	Inflow to San Luis Drain @ Ck 17	4630	7.7	—	—	67.4	28	—	—	—	—	—	—
D	San Luis Drain @ Terminus	4760	7.7	635	1700	54.4	26	7.8	3.7	5.9	<5	—	1250
B	Mud Slough (N) Upstream of SLD	1200	1.1	165	200	1.0	5	9.5	7.7	15	<5	—	280
O	Mud Slough dwnstrm of SLD	2640	3.3	370	855	22.9	15	11	4.8	11	<5	—	675
D	San Luis Drain @ Terminus*	4730	7.9	—	—	56.4	—	—	—	—	—	—	—

See Table 2 for sampling frequency. I = Inflow O = Outflow D = agricultural drainage
—: Not analyzed T = Internal flow B = background
*Autosampler Daily Composite Data for EC, B, and Se only.

Table 5. Annual Minimum, Mean, and Maximum Electrical Conductivity, Boron, and Selenium at Monitoring Sites Within the Grassland Watershed: Water Years 86-97, and 1998.

Site	Count	EC (umhos/cm)			Boron (mg/L)			Selenium (ug/L)		
		Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Agatha Canal										
WYs 86-97	284	162	2660	8100	0.07	4.2	20	0.5	30.7	120
WYs 86-97(critical)	153	430	3310	8100	0.07	5.4	20	0.8	37.6	114
WYs 86-97 (wet)	130	162	1920	6600	0.11	2.8	15	0.5	22.6	120
WY 98	***52***	***66***	***875***	***3370***	***<0.05***	***1.3***	***6.1***	***<0.4***	***4.0***	***40.4***
Camp 13 Slough										
WYs 86-97	313	172	3190	6700	0.13	4.5	10	0.6	45.9	144
WYs 86-97(critical)	185	390	3690	6700	0.22	5.1	10	1.0	53.1	123
WYs 86-97 (wet)	126	172	2470	6510	0.13	3.5	9.3	0.6	35.2	144
WY 98	***51***	***64***	***1430***	***6610***	***<0.05***	***2.6***	***13***	***<0.4***	***2.4***	***11.5***
CCID Main Canal										
WYs 86-95	214	50	686	3790	<0.05	0.40	5.1	<0.4	1.9	16.0
WYs 86-95(critical)	176	55	719	3790	0.10	0.40	5.1	<0.4	1.9	5.2
WYs 86-95 (wet)	37	50	572	2100	<0.05	0.41	2.7	<0.4	1.9	16.0
WY 98 (Feb. through Sept. only)	***34***	***43***	***279***	***1000***	***<0.05***	***0.22***	***1.1***	***<0.4***	***1.5***	***3.9***
Santa Fe Canal @ Henry Miller Road										
WYs 93-97	142	188	1150	4090	0.10	1.2	5.4	<0.4	5.3	59.8
WYs 93-97(critical)	40	410	1170	4090	0.22	1.1	5.3	<0.4	6.2	59.8
WYs 93-97 (wet)	102	188	1130	3930	0.10	1.2	5.4	0.6	4.9	44.0
WY 98	***51***	***341***	***1150***	***2420***	***0.20***	***1.5***	***4.2***	***0.7***	***2.4***	***13.0***
Santa Fe Canal @ weir										
Aug. & Sept. WY 98	***6***	***356***	***816***	***1710***	***0.26***	***0.80***	***1.7***	***1.1***	***1.9***	***2.7***
San Luis Canal @ Henry Miller Road										
WYs 93-97	168	196	1460	4850	0.10	1.7	7.4	0.7	11.1	74.0
WYs 93-97(critical)	50	484	1220	4010	0.30	1.2	4.9	0.7	7.0	56.6
WYs 93-97 (wet)	118	196	1570	4850	0.10	1.9	7.4	0.8	12.8	74.0
WY 98	***52***	***350***	***1220***	***2560***	***0.24***	***1.7***	***4.5***	***0.8***	***2.5***	***10.5***
San Luis Canal @ splits										
Aug. & Sept. WY 98	***7***	***339***	***477***	***719***	***0.19***	***0.35***	***0.61***	***1.0***	***1.6***	***3.3***
Salt Slough @ Lander Ave.										
WYs 86-97	564	780	2140	4050	0.30	2.0	5.0	0.5	13.8	44.0
WYs 86-97(critical)	351	1020	2230	4050	0.30	2.0	4.7	0.6	14.6	44.0
WYs 86-97 (wet)	211	780	1990	3970	0.40	1.8	5.0	0.5	12.5	42.0
WY 98	***52***	***557***	***1440***	***2730***	***0.21***	***0.89***	***1.9***	***0.4***	***1.2***	***5.1***
Inflow to San Luis Drain @ Check 17										
WY 97	48	2620	4460	5600	4.2	7.3	9.0	17.9	65.9	108
WY 98	***52***	***2040***	***4730***	***6230***	***3.3***	***7.7***	***11***	***19.2***	***70.4***	***133***
San Luis Drain @ Terminus										
WY 97	48	2720	4270	5460	4.4	6.8	8.4	17.0	59.3	107
WY 98	***53***	***2950***	***4780***	***6070***	***4.4***	***7.7***	***9.9***	***34.0***	***66.6***	***120***
Mud Slough (N) upstream of SLD										
WY 97	48	744	1390	2960	0.56	1.2	2.9	<0.4	0.8	1.7
WY 98	***51***	***595***	***1300***	***3170***	***0.47***	***1.3***	***3.3***	***<0.4***	***1.0***	***1.9***
Mud Slough (N) @ San Luis Drain										
WYs 91-97	384	588	3080	10860	0.20	2.8	8.7	0.4	9.7	79.6
WYs 91-97(critical)	190	660	3870	10860	0.20	3.4	7.9	0.4	10.3	50.0
WYs 91-97 (wet)	194	588	2300	7250	0.27	2.2	8.7	0.4	9.1	79.6
WY 98	***52***	***1100***	***2720***	***5340***	***1.1***	***3.8***	***8.9***	***3.1***	***26.6***	***104***
Autosampler Data										
San Luis Drain @ Terminus										
WY 97	344	2620	4390	5880	4.1	7.0	9.3	15.2	62.4	116
WY 98	***363***	***2430***	***4790***	***6330***	***1.4***	***7.8***	***11***	***20.2***	***66.9***	***134***

Count = the minimum number of analyses out of the three constituents

Water year type is based on the San Joaquin 60-20-20 River Index as follows:

Critical Water Year: Runoff < 2.1 million ac-ft (WYS 87-92 and 94)

Wet Water Year: Runoff > 3.81 million ac-ft (WYs 86, 93, 95, 96, and 97)

San Luis Drain and Mud Slough (north)

Grab samples were collected both from the inflow to and discharge from the San Luis Drain and also from Mud Slough (north) upstream and downstream of the discharge from the San Luis Drain. In addition to EC, boron, and total selenium, dissolved selenium and total suspended solids were analyzed at both San Luis Drain sites.

Concentrations at the inflow to and discharge from the San Luis Drain were similar (Figure 3). EC and boron concentrations remained fairly consistent over the year near 4700 umhos/cm and 7.7 mg/L, respectively, for both the inflow and discharge. Selenium concentrations were more variable, ranging from 19.2 ug/L to 133 ug/L. All three constituents concentrations dropped significantly during February 1998 when flows were a mixture of subsurface agricultural drainage and stormwater flood flows.

Discharge from the San Luis Drain had a pronounced impact on Mud Slough (north) (Figure 4), particularly after February 1998. Elevated background concentrations of EC and boron in Mud Slough (north) upstream of the San Luis Drain discharge (reaching 3170 umhos/cm and 3.3 mg/L, respectively) are further exacerbated by the drainage discharge, with EC and boron concentrations reaching 5340 umhos/cm and 8.9 mg/L, respectively. The greatest impact on Mud Slough from the San Luis Drain discharge was on selenium concentrations. Selenium concentrations in Mud Slough (north) upstream of the discharge were below 1.9 ug/L; downstream of the discharge, the mean selenium concentration was 26.6 ug/L with a maximum of 104 ug/L.

A comparison of total versus dissolved selenium concentrations at the two San Luis Drain sites is presented in Table 6. Concentrations of each sample pair fall within the analytical criteria of acceptable split samples (90-110% recoveries), indicating that selenium in the drain is in the dissolved (aqueous) form.

Total suspended sediment was analyzed on a weekly basis in the inflow to and discharge from the San Luis Drain. Summary results from the analyses are presented in Table 7 and Figure 5. Complete analytical results are listed in Appendix A. Total suspended sediment concentrations were consistently higher in the inflow to the drain than in the discharge from the drain, although actual weekly concentrations varied widely. Median concentrations in the inflow and discharge were 130 mg/L and 46 mg/L, respectively. The differences in concentrations between the two sites indicates that water velocities are such that sediments are being deposited in the San Luis Drain. Scouring and mobilization of resident San Luis Drain sediments does not appear to be occurring.

Wetland Water Supply Channels and Salt Slough

Weekly grab samples were collected at: CCID Main Canal (from 4 February 1998 through 30 September 1998), Camp 13 Ditch and the Agatha Canal, major supply canals for wetlands within Grassland Water District; the San Luis Canal and Santa Fe Canal at Henry Miller Road, two internal distribution canals for wetland habitat; and at Salt Slough, a tributary of the San Joaquin River. Between 3 and 28 February 1998, subsurface agricultural drainage was diverted into these channels in response to a flood event. Information concerning the flood event and diversion has been presented and discussed in a previous report (GAF, 1998) and is not included in the following discussion.

Figure 3. Electrical Conductivity, Boron and Selenium Concentrations in the Inflow to and Discharge from the San Luis Drain (Grab Data): Water Year 1998

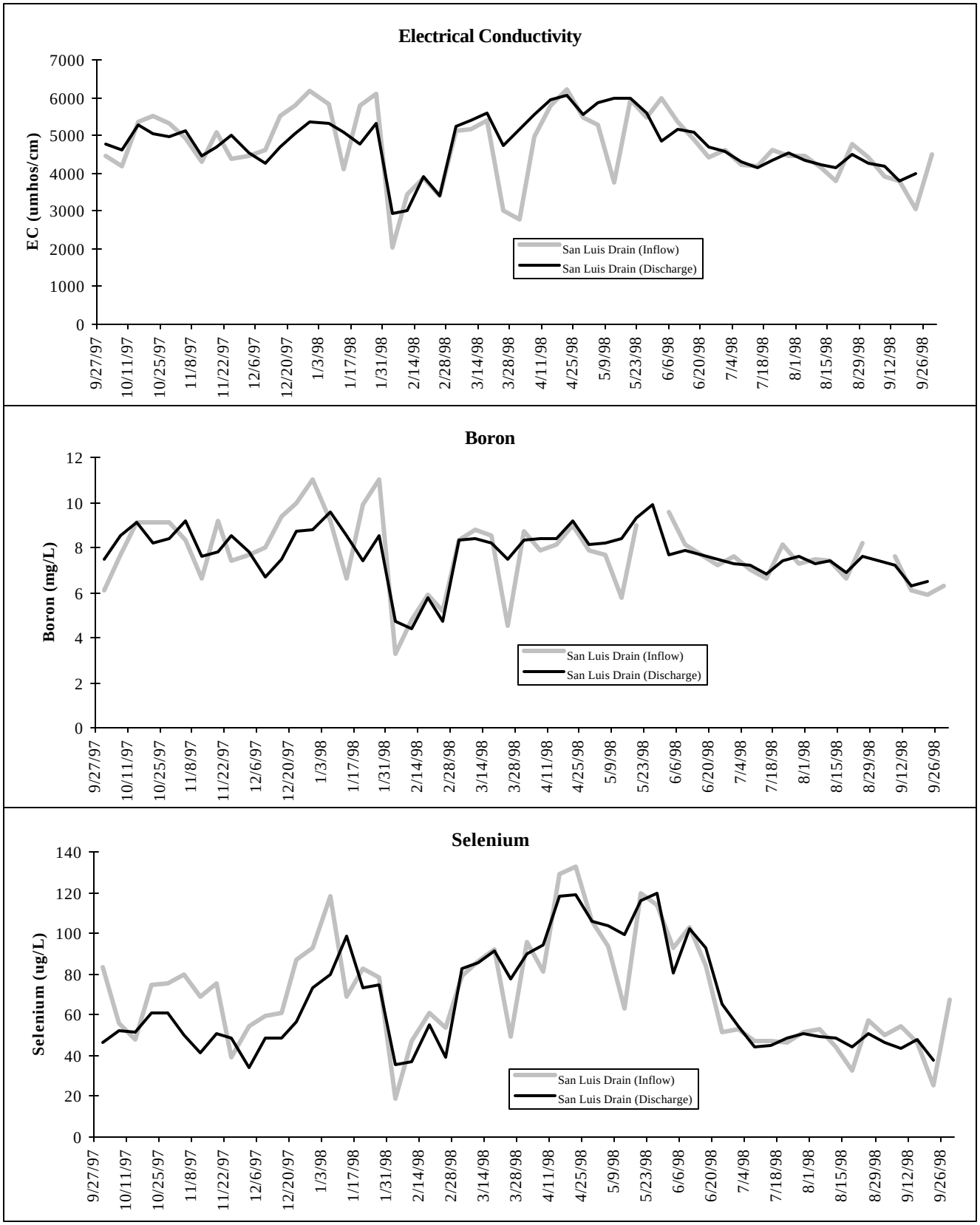


Figure 4. Electrical Conductivity, Boron and Selenium Concentrations in Mud Slough (north) Upstream and Downstream of the Discharge from San Luis Drain (Grab Data): Water Year 1998

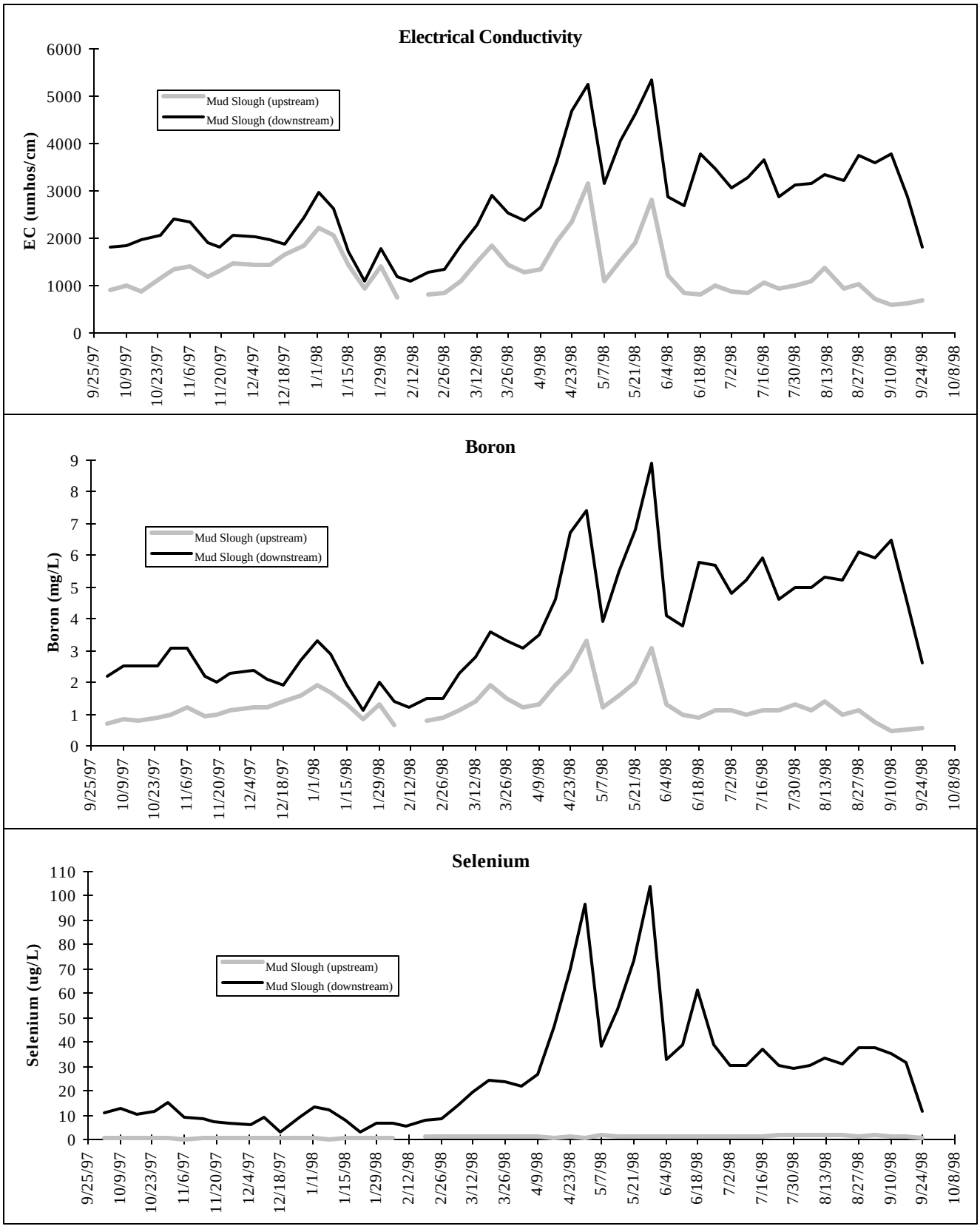


Table 6. Total vs Dissolved Selenium Concentrations at the Inflow to and Discharge from the San Luis Drain: Water Year 199

Dates*	Selenium Concentration (ug/L)			
	Inflow		Outflow	
	Total	Dissolved	Total	Dissolved
10/1-2/97	83.6	80.5	46.6	45.1
10/8-9/97	55.8	55.6	52.2	52.6
10/15-16/97	48.1	47.3	51.6	51.6
10/22-24/97	74.8	75.1	60.8	60.2
10/29-30/97	75.6	78.2	61.0	60.9
11/5-6/97	79.5	77.2	50.3	50.5
11/12-14/97	68.8	69.2	41.6	43.3
11/19/97	75.4	74.6	51.0	50.2
11/25/97	39.4	38.8	48.8	50.6
12/3-5/97	54.2	54.5	34.0	33.9
12/10-11/97	59.3	57.2	48.9	49.0
12/17-18/97	60.6	64.3	48.9	51.8
12/23-26/97	87.1	84.2	56.8	56.8
12/30/97-1/2/98	92.5	91.7	73.0	73.0
1/7-8/98	118	118	80.1	80.1
1/14-15/98	68.6	67.9	98.9	100
1/21-22/98	82.5	81.7	73.5	73.2
1/28-29/98	78.2	77.4	74.4	75.4
2/4-5/98	19.2	18.4	35.5	33.4
2/11/98	47.4	45.9	37.0	36.6
2/18-19/98	61.2	58.4	55.0	54.4
2/25-26/98	53.4	50.8	39.0	42.6
3/4-5/98	79.0	76.8	82.4	80.5
3/11-12/98	86.2	85.6	85.8	88.8
3/18-19/98	92.4	91.5	91.5	90.9
3/25-26/98	49.0	50.6	77.6	79.4
4/1-2/98	95.6	92.6	90.0	92.8
4/8-9/98	81.1	77.7	94.6	93.0
4/15-16/98	129	130	118	120
4/22-23/98	133	126	119	119
4/29-30/98	106	105	106	106
5/6-7/98	93.4	92.4	104	104
5/13-14/98	62.8	60.7	99.2	99.4
5/20-21/98	120	120	116	119
5/27-28/98	114	112	120	120
6/3-4/98	92.9	92.8	80.6	80.6
6/10-11/98	103	101	102	98.4
6/17-18/98	84.2	81.8	92.8	91.0
6/24-25/98	51.2	49.2	65.6	68.9
7/1-2/98	52.8	50.5	54.4	56.5
7/8-9/98	47.0	46.1	44.4	44.2
7/15-16/98	47.2	44.0	45.1	43.6
7/22-23/98	46.1	44.1	48.3	46.9
7/29-30/98	51.6	51.4	50.5	50.6
8/5-6/98	52.6	51.6	49.2	48.1
8/12/98	44.2	42.6	48.4	48.3
8/19-20/98	32.6	33.1	44.4	44.2
8/26-27/98	57.5	57.4	51.0	52.4
9/2-3/98	50.1	49.4	46.1	46.8
9/9-10/98	54.4	51.9	43.5	42.5
9/16-17/98	46.3	47.2	48.2	48.4
9/23-24/98	25.4	22.2	37.4	32.2
9/30/98	67.4	65.2		

*Where indicated, samples were collected one or two days earlier at the inflow sampling site

Beginning 12 August 1998, two additional sites were added to the monitoring program: San Luis Canal at the Splits and Santa Fe Canal at the Weir. Both sites are upstream of Henry Miller Road and upstream of potential commingling of the two water bodies. Prior to the use of the Grassland Bypass, subsurface agricultural drainage was typically directed down the San Luis Canal and into Porter-Blake Bypass for discharge into Salt Slough. On some occasions, the drainage would flow down the Santa Fe Canal for discharge into Mud Slough (north). After October 1996, use of Porter-Blake Bypass for drainage ended and flows between the two canals were allowed to commingle upstream of the historic sampling locations on Henry Miller Road. Relocating the sampling sites upstream of the mixing location allows the evaluation of water quality from two separate drainage areas.

EC, boron and selenium data for Camp 13 Slough and Agatha Canal are presented in Figure 6. Concentrations in the two water bodies fluctuated greatly over short time periods. Camp 13 Slough had higher mean EC (1420 vs. 960 umhos/cm) and boron (2.7 vs. 1.3 mg/L) concentrations than the Agatha Canal. Electrical conductivity in Camp 13 Slough exceeded 4000 umhos/cm on a number of occasions with corresponding spikes in boron concentration. The EC and boron concentrations in the Agatha Canal remained well below 1000 umhos/cm and 1 mg/L, respectively, except for two distinct spikes, one occurring during mid January through mid March and the other occurring during April.

Figure 5. Total Suspended Sediment Concentrations in the Inflow to and Discharge from the San Luis Drain: Water Year 1998

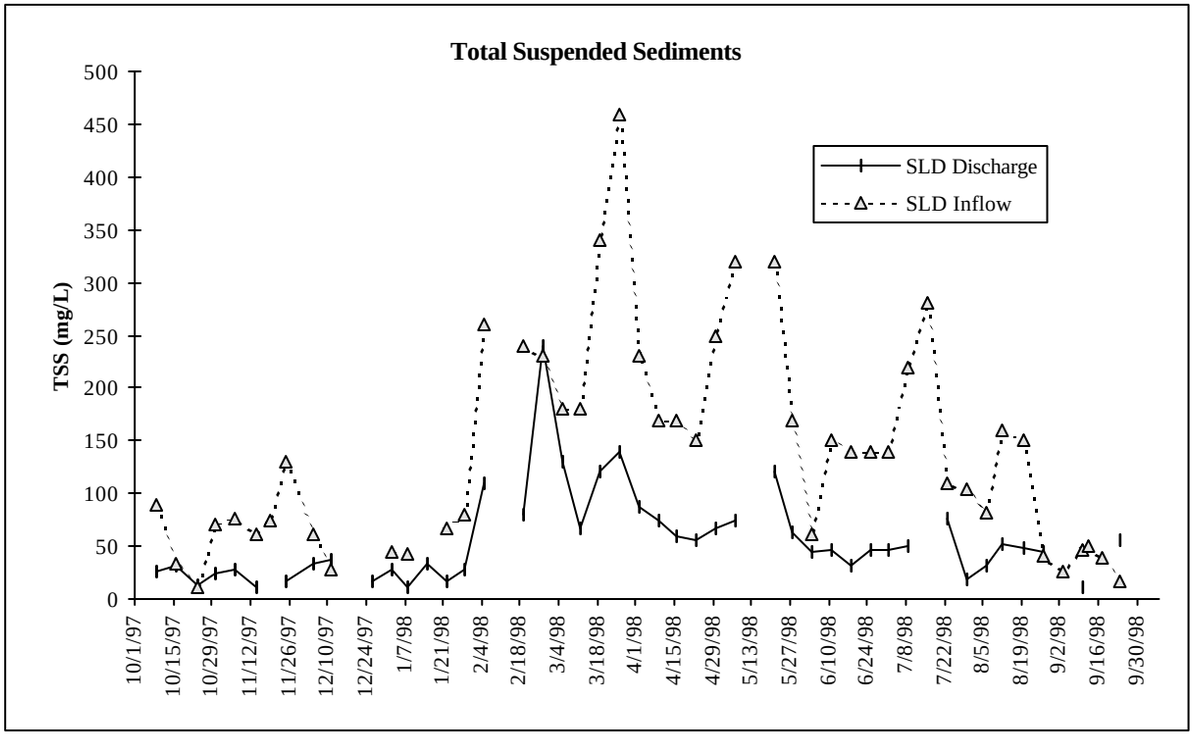
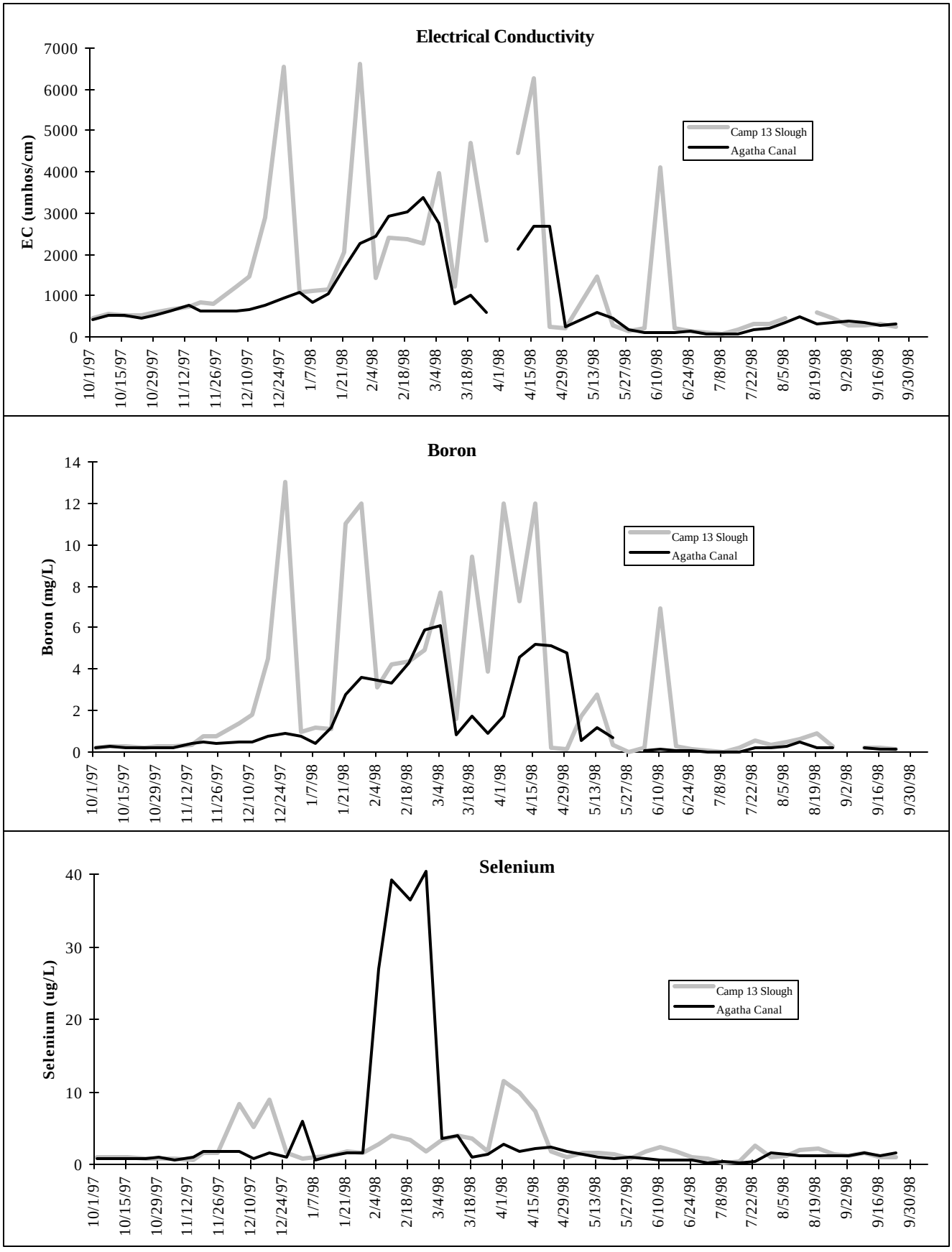


Table 7. Summarized Total Suspended Sediment Data for the Inflow to Discharge from the San Luis Drain: Water Year 1998

San Luis Drain Location	Total Suspended Sediment					
	Count	Min	Mean	Geo Mean	Median	Max
Inflow to	47	12	138	103	130	460
Discharge from	44	11	56	43	46	240

Camp 13 Slough and the Agatha Canal are primarily water supply channels for wetland habitat, whose water quality is expected to reflect that of their supply water, the CCID Main Canal. Until March 1998, subsurface drainage was diverted into these two supply channels. Until 21 April 1998, seepage from drainage control gates also entered the two channels. Once drainage was removed from the channels, overall water quality improved. Electrical conductivity concentrations elevated over those of the CCID Main Canal, continued in Camp 13 Slough and Agatha Canal until wetland floodup began in September 1998. Most of the elevated concentrations appear to be related to periods of low flow, indicating potential impacts from evapoconcentration and/or local groundwater influences. For example, an EC of 4100 umhos/cm and boron of 6.9 mg/L were recorded during June 1998, when flow in Camp 13 was reported at less that 1 cfs (C. Linnemann, personal communication). Groundwater concentrations in the area have been recorded at 1600 to 3100 umhos/cm and greater than 4 mg/L boron (Lowry, 1989).

Figure 6. Electrical Conductivity, Boron and Selenium Concentrations in Camp 13 Slough and Agatha Canal (Grab data): Water Year 1998



Selenium concentrations in the Agatha Canal show the diversion of stormwater flow into this water body during February. During the period of diversion, selenium concentrations rapidly rose above 30 ug/L and peaked at 40.4 ug/L. During the remainder of WY98, selenium concentrations in the Agatha Canal remained near or below 2 ug/L.

In contrast, selenium concentrations in Camp 13 Slough show a number of relatively smaller increases (maximum concentration of 11.5 ug/L) between December 1997 and April 1998. These increases have been attributed to leakage of drainage through control gates and diversion of stormwater flow (GAF, 1998). On 21 April 1998, the leakages were sealed which resulted in selenium concentrations returning to less than 2 ug/L.

Concentrations in the internal supply channels, the San Luis and Santa Fe Canals, fluctuated during Water Year 1998, as depicted in Figure 7. EC for both canals remained near 2000 umhos/cm between December 1997 and April 1998. Boron concentrations followed the same elevated pattern with concentrations exceeding 2 mg/L between December and April. Maximum boron concentrations reached 4.2 and 4.5 mg/L in the Santa Fe Canal and San Luis Canal, respectively, during mid-April 1998. April typically corresponds to a period of maximum wetland water releases and pre-irrigation. The selenium pattern in the two canals shows two distinct peaks, one in early December 1997 and another during February 1998. The elevated selenium concentrations during February (maximum concentrations reaching 13.0 and 10.5 ug/L in the Santa Fe and San Luis Canals, respectively), correspond to the diversion of stormwater flows.

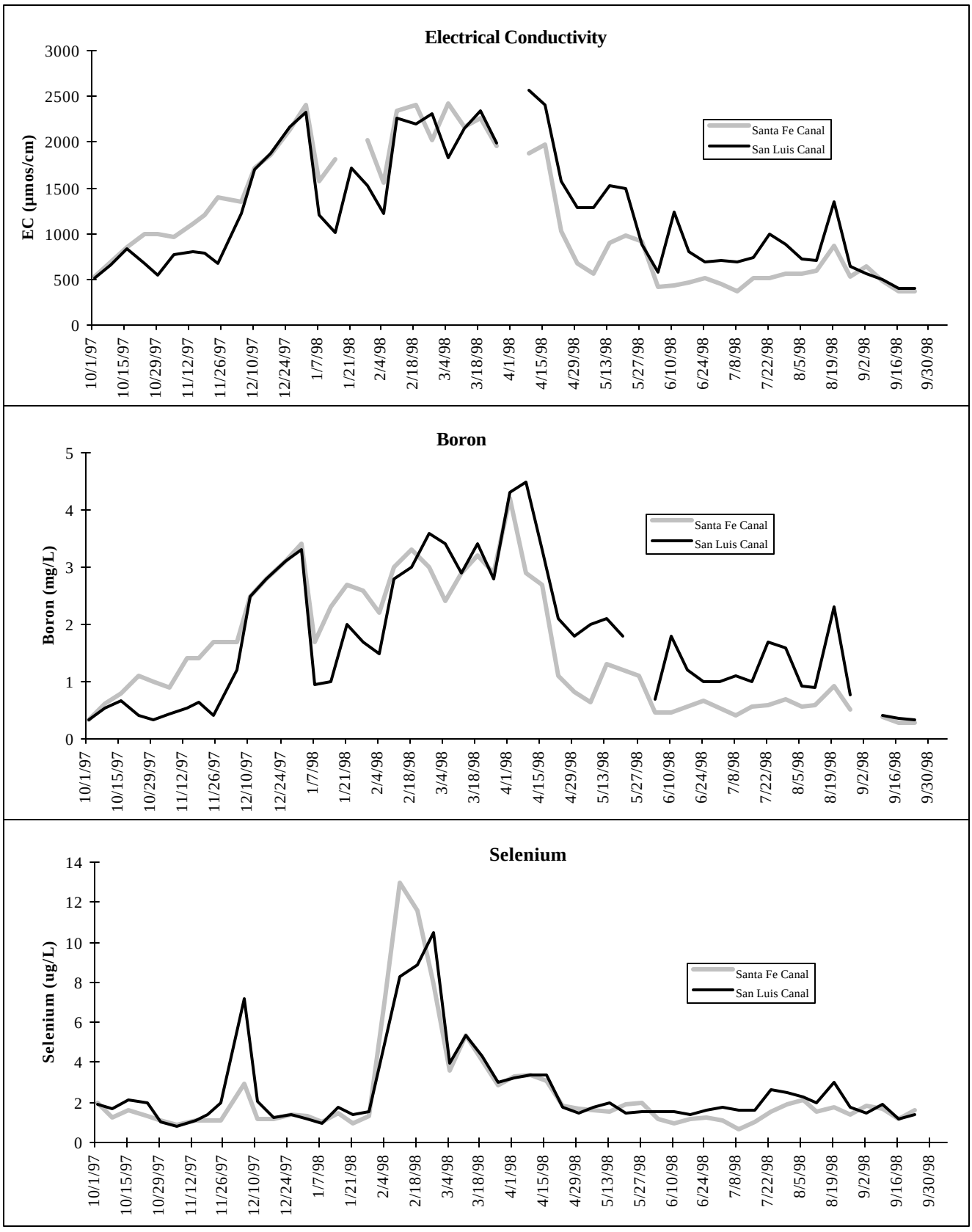
Although the San Luis and Santa Fe Canals do represent internal water quality for channels in the Grassland Watershed, the location of sample collection, at Henry Miller Road, is downstream of an area where water in the two canals can commingle. Similar results for the two locations may be indicative of upstream mixing of the water bodies. Two new sampling sites were initiated after 12 August 1998 upstream of the juncture of the two water bodies. Although data is currently too limited to thoroughly evaluate, some differences in concentrations at the upstream and downstream locations is apparent for both canals (Table 8). The upstream sites will be maintained during WY99.

Table 8. Comparison of Constituent Concentrations at Various Locations on the Santa Fe and San Luis Canals: Water Year 1998

Site	Number of Samples	EC (umhos/cm)			Se (ug/L)			Boron (mg/L)		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Santa Fe Canal:										
Henry Miller (MER519)	51	341	868	524	1.1	1.8	1.5	0.20	0.93	0.46
Weir (MER545)*	6	356	1710	816	1.1	2.7	1.9	0.26	1.7	0.80
San Luis Canal:										
Henry Miller (MER532)	52	350	1350	614	1.1	3.0	1.7	0.24	2.3	0.76
Splits (MER563)*	7	339	719	477	1.0	3.3	1.6	0.19	0.61	0.35

*Samples only collected during August and September 1998

Figure 7. Electrical Conductivity, Boron and Selenium Concentrations in Santa Fe Canal and San Luis Canal @ Henry Miller Road: Water Year 1998



The majority of elevated selenium concentrations in Camp 13 Slough and the Agatha Canal can be explained by diversion of stormwater and or leakage from control gates. The pattern of elevated selenium concentrations downstream at the San Luis and Santa Fe Canals is more variable. A preliminary study was conducted by the Regional Board to evaluate selenium concentrations in wetland water supply channels within the Grassland Watershed (Chilcott, 1999). Although the primary cause of elevated selenium in internal channels during Water Year 1998 was diversion of stormwater flow, other sources were identified which included supply water, areas of subsurface agricultural drainage outside of the DPA, tail water runoff and local groundwater seepage. Further evaluation of these sources is being conducted as a separate study by the Regional Board and local water agencies and has not been discussed in this report.

Concentrations of EC, boron, and selenium in Salt Slough during Water Year 1998, are depicted in Figure 8. Periods of elevated EC and boron (above 1500 umhos/cm and 1.5 mg/L, respectively) are evident between December 1997 and April 1998. Selenium concentration remained below 2.0 ug/L except for an elevated period recorded from late February to mid-March 1998. This period of elevated concentrations corresponded to diversions of stormwater flood flows and peaked at 5.1 ug/L on 26 February 1998.

Daily Composite Samples

Daily composite samples were collected at the discharge from the San Luis Drain. Daily electrical conductivity (EC), boron and selenium results are presented in Figure 9 along with grab sample data.

At the San Luis Drain discharge, EC and boron concentrations can vary widely on a daily basis. Daily EC values vary up to 1,000 umhos/cm in a day, while boron concentrations vary up to 2 mg/L per day. Some seasonality is evident with concentrations peaking between April and June and tapering off from June through September. A marked decrease in both constituent concentrations occurred during February and corresponds to the period of heavy precipitation and diversion of stormwater and flood flows. The results obtained from the grab and autosampler show similar means and medians of 4780 umhos/cm and 4790 umhos/cm, respectively for EC and 7.7 and 7.8 mg/l, respectively for boron (Table 5).

Selenium showed greater seasonal fluctuations than EC or boron, with concentrations peaking in April at 134 ug/L and dropping off to 20.2 ug/L in September. Daily concentration fluctuations could also be high, with concentrations frequently fluctuating by 20 ug/L and with a 36.6 ug/L shift occurring between 7 and 8 December 1997. Although weekly grab samples appear to document the seasonal trends and shifting concentrations, they are unable to detect the potentially large changes in daily concentrations.

DISCUSSION

Comparison to Pre-Project Conditions and Water Year 1997

When the Grassland Bypass became operational at the end of September 1997, it effectively consolidated agricultural subsurface drainage from the DPA into a single channel for discharge into the

Figure 8. Electrical Conductivity, Boron and Selenium Concentrations in Salt Slough (Grab data): Water Year 1998

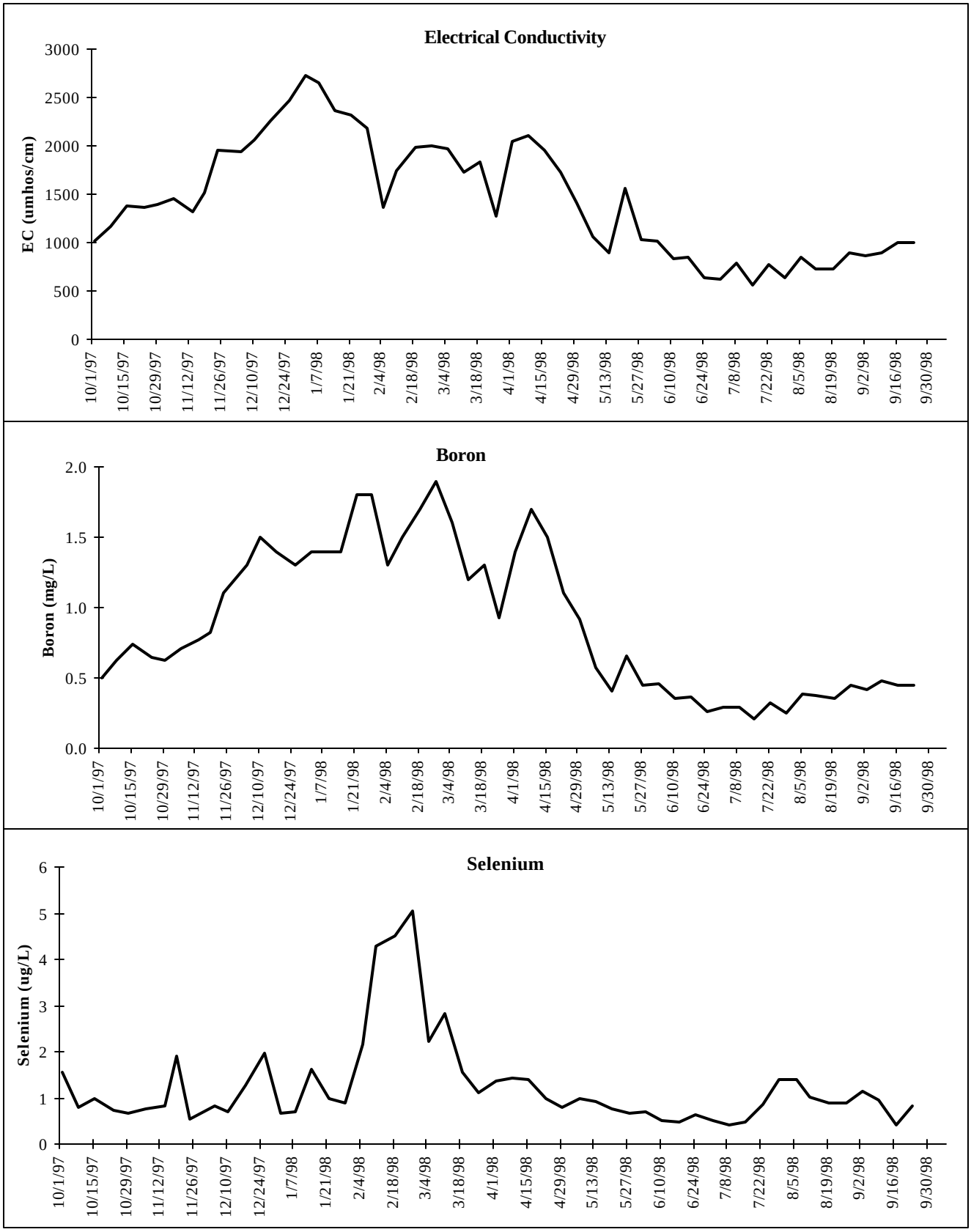
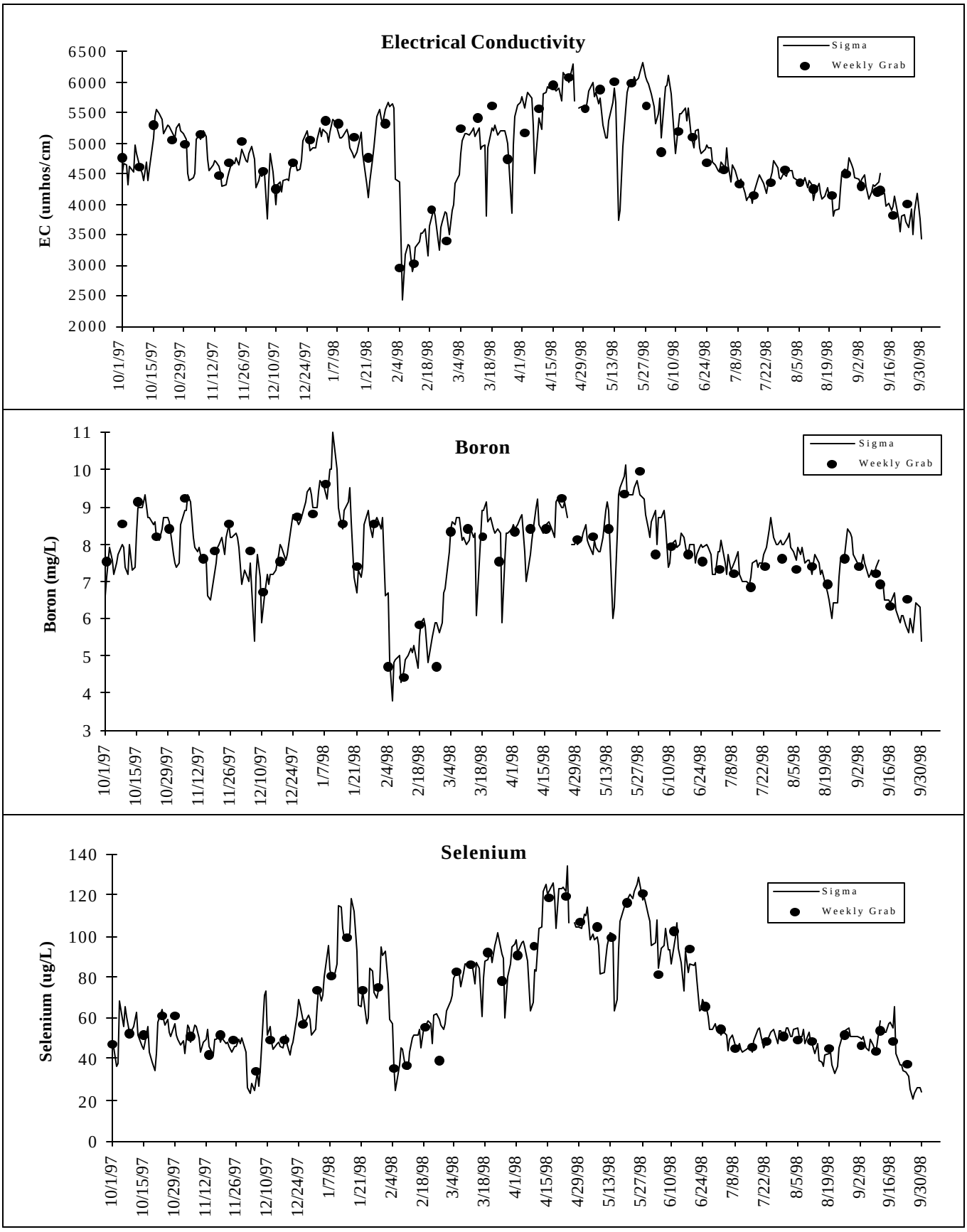


Figure 9. Comparison of Electrical Conductivity, Boron and Selenium in the San Luis Drain Using Grab Sample Data and Autosampler (Sigma) Data: Water Year 1998



final nine miles of Mud Slough (north). This consolidation removed the subsurface drainage from approximately 90 miles of internal wetland water supply channels and from Salt Slough.

Table 9 lists minimum, mean, and maximum electrical conductivity, boron and selenium concentrations for wet water years 1997 and 1998 as well as a summary for all the wet water years that occurred between water years 1986 and 1996 (pre-project). Although there is little change in water quality at the sites monitored between the first and second years following the operation of the Grassland Bypass Project (between WY97 and WY98), notable differences do occur pre- and post-project. Both EC and boron concentrations declined in Salt Slough and increased in Mud Slough (north) after the Bypass began operation. The most dramatic change, however, occurred with selenium concentrations. Removing the agricultural subsurface drainage from Salt Slough, reduced the mean selenium concentration to below 2.0 ug/L during both WY97 and WY98 as opposed to a range of 0.5 to 42.0 ug/L and a mean of 15.8 ug/L during pre-project wet years. A corresponding increase was seen in Mud Slough (north) with mean selenium concentrations at 30.7 ug/L during WY97 and 26.6 ug/L during WY98 as compared to a mean of 2.4 ug/L during preproject wet years. When subsurface agricultural drainage is present, the higher overall selenium concentrations observed in Mud Slough (north), as compared to Salt Slough, is due to limited dilution potential. Mud Slough (north) has a lower baseline flow and therefore provides less dilution for agricultural subsurface drainage than Salt Slough.

Concentrations in the wetland water supply channels was more variable. Overall concentrations in Camp 13 Slough and the Agatha Canal decreased dramatically after the Bypass began operation. A number of concentration spikes did occur throughout WY97 and WY98. Potential reasons for the concentration spikes include elevated selenium levels in supply water, releases from the DPA (seepage and flood flows), inflows from other sources such as the Rice Drain and Almond Drive Drain, and other internal sources such as groundwater seepage and surface return flows. These potential sources underwent a preliminary review in Chilcott (1999).

Changes in concentrations in the San Luis Canal and Santa Fe Canal are more difficult to judge, with lower concentrations recorded in both canals during WY97 and higher concentrations recorded in the Santa Fe Canal during WY98 (Table 9). During pre-project conditions, most subsurface agricultural drainage was diverted out of these canals and into Salt Slough through the Porter-Blake Bypass, upstream of the sampling locations. Only when subsurface agricultural drainage was diverted to Mud Slough (north) or continued downstream in the San Luis Canal to the City Ditch diversion to Salt Slough, would the drainage be measured in these canals at these sampling locations. By water year 1997, the majority of subsurface drainage had been consolidated into the Grassland Bypass and lower portion of the San Luis Drain, and did not reach the two canals except during flood flows.

Comparison to Applicable Water Quality Objectives

In October 1988, the Regional Board adopted water quality objectives for boron, molybdenum and selenium for Mud Slough (north), Salt Slough and water used to maintain wetland habitat. In May 1996, the Regional Board adopted revised selenium water quality objectives for the two sloughs and for wetland water supply channels, as well as a compliance time schedule for Mud Slough (north). Water quality objectives which applied during each water year are listed in Table 10. The selenium compliance time schedule which applies to Mud Slough (north), does not require compliance with the

Table 9. Annual Minimum, Mean, and Maximum Electrical Conductivity, Boron, and Selenium at Monitoring Sites Within the Grassland Watershed: Wet Water Years 86-96, 1997 and 1998.

Site	Count	EC (umhos/cm)			Boron (mg/L)			Selenium (ug/L)		
		Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Agatha Canal										
WYs 86-96 (Wet Years only)	86	162	2650	6600	0.12	4.1	15	0.9	33.0	120
WY 97	43	187	518	4240	0.11	0.25	0.46	0.5	1.3	3.4
WY 98	52	66	875	3370	<0.05	1.3	6.1	<0.4	4.0	40.4
Camp 13 Slough										
WYs 86-96 (Wet Years only)	83	266	3330	6510	0.13	4.8	9.3	0.8	51.5	144
WY 97	42	172	822	3760	0.15	1.1	7.1	0.6	2.6	23.4
WY 98	51	64	1430	6610	<0.05	2.6	13	<0.4	2.4	11.5
CCID Main Canal										
WYs 86-96 (Wet Years only)	37	50	572	2100	<0.05	0.41	2.7	0.6	1.9	16.0
WY 97 (No data available)	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
WY 98	33	43	279	1000	<0.05	0.22	1.1	<0.4	1.5	3.9
Santa Fe Canal @ Henry Miller Road										
WYs 93-96 (Wet Years only)	59	188	1270	3930	0.10	1.4	5.4	0.6	7.0	44.0
WY 97	42	339	941	1870	0.24	1.0	2.9	0.8	2.1	3.9
WY 98	51	341	1150	2420	0.20	1.5	4.2	0.7	2.4	13.0
Santa Fe Canal @ weir										
Aug. & Sept. WY 98	6	356	816	1710	0.26	0.80	1.7	1.1	1.9	2.7
San Luis Canal @ Henry Miller Rd										
WYs 93-96 (Wet Years only)	76	196	1880	4850	0.10	2.4	7.4	0.8	18.6	74.0
WY 97	41	501	973	1840	0.36	1.1	3.3	1.0	2.1	6.2
WY 98	52	350	1220	2560	0.24	1.7	4.5	0.8	2.5	10.5
San Luis Canal @ splits										
Aug. & Sept. WY 98	7	339	477	719	0.19	0.35	0.61	1.0	1.6	3.3
Mud Slough (N) @ San Luis Drain										
WYs 91-96 (Wet Years only)	147	588	2110	7250	0.27	1.6	8.7	<0.4	2.4	59.0
WY 97	46	1150	2870	4930	1.1	4.1	6.8	5.0	30.7	79.6
WY 98	52	1100	2720	5340	1.1	3.8	8.9	3.1	26.6	104
Salt Slough @ Lander Ave.										
WYs 86-96 (Wet Years only)	163	780	2170	3970	0.43	2.2	5.0	0.5	15.8	42.0
WY 97	48	922	1370	2000	0.40	0.77	1.8	0.5	1.0	3.4
WY 98	52	557	1440	2730	0.21	0.89	1.9	0.4	1.2	5.1
Inflow to San Luis Drain @ Check 17										
WY 97	48	2620	4460	5600	4.2	7.3	9.0	17.9	65.9	108
WY 98	52	2040	4730	6230	3.3	7.7	11	19.2	70.4	133
San Luis Drain @ Terminus										
WY 97	48	2720	4270	5460	4.4	6.8	8.4	17.0	59.3	107
WY 98	53	2950	4780	6070	4.4	7.7	9.9	34.0	66.6	120
Mud Slough (N) upstream of SLD										
WY 97	48	744	1390	2960	0.56	1.2	2.9	<0.4	0.8	1.7
WY 98	51	595	1300	3170	0.47	1.3	3.3	<0.4	1.0	1.9
Autosampler Data										
San Luis Drain @ Terminus										
WY 97	344	2620	4390	5880	4.1	7.0	9.3	15.2	62.4	116
WY 98	363	2430	4790	6330	1.4	7.8	11	20.2	66.9	134

Count = the minimum number of analyses out of the three constituents

Water year type is based on the San Joaquin 60-20-20 River Index as follows:

Critical Water Year: Runoff < 2.1 million ac-ft (WYS 87-92 and 94)

Wet Water Year: Runoff > 3.81 million ac-ft (WYs 86, 93, 95, 96, and 97)

Table 10. Boron, Selenium and Molybdenum Water Quality Objectives for Water Bodies Within the Grassland Watershed Water Year 1998.

Water Body	Boron (mg/L)		Selenium (ug/L)		Molybdenum (ug/L)	
	Continuous	Maximum	Continuous	Maximum	Continuous	Maximum
Mud Slough (north)						
WY 1996	2.0 (monthly mean)†	5.8	10 (monthly mean)	26	19 (monthly mean)	50
WY 1997 & 98	2.0 (monthly mean)†	5.8	5 (4-day average)*	20	19 (monthly mean)	50
Salt Slough						
WY 1996	2.0 (monthly mean)†	5.8	10 (monthly mean)	26	19 (monthly mean)	50
WY 1997 & 98	2.0 (monthly mean)†	5.8	2 (monthly mean)	20	19 (monthly mean)	50
Wetland Water Supply Channels						
WY 1996	—	—	2 (monthly mean)††	—	—	—
WY 1997 & 98	—	—	2 (monthly mean)	20	—	—

† = The water quality objective only applies from 15 March through 15 September
* = Compliance time schedule adopted and in effect until October 2010
†† = as measured in water used for wetland habitat maintenance

selenium objective until 1 October 2010. No water quality objectives have been adopted for the San Luis Drain.

Tables 11 and 12 list the exceedances of boron water quality objectives and the months when selenium concentrations exceeded the 2 ug/L water quality objective in the wetland water supply channels and 5 ug/L in the remaining water bodies, respectively, for Water Year 1998. Calculations of monthly means were based on all data collected during the calendar month.

Boron

The boron water quality objective only applies to two water bodies, Mud Slough (north) and Salt Slough. In addition, the objective (2.0 mg/L) is applied as a monthly mean for a set time period: 15 March through 15 September. A maximum objective of 5.8 mg/L boron applies year round.

During Water Year 1998, the mean monthly boron objective was only exceeded in Mud Slough (north) downstream of the San Luis Drain discharge. Concentrations in Mud Slough (north) upstream of the San Luis Drain discharge, although elevated, did not exceed 2.0 mg/L between March and September. Exceedances in the slough downstream of the discharge occurred during each month that the water quality objective applied. Maximum boron concentrations in Mud Slough (north) downstream of the San Luis Drain discharge exceeded 5.8 mg/L on six separate occasions between April and September 1998. Boron concentrations in Salt Slough did not exceed the water quality objective and remained below 1.9 mg/L throughout Water Year 1998

Selenium

New selenium water quality objectives, were adopted in May 1996 and went into effect on 10 January 1997. These objectives included a 2 ug/L monthly mean selenium objective for all wetland water supply channels and Salt Slough. A 5 ug/L, 4-day average objective was adopted for Mud Slough

Table 11. Boron Water Quality Objective Exceedances in the Grassland Watershed: Water Year 1998.

Station ID	Description	Mean Monthly Concentration (mg/L)												Monthly WQO
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
MER536	Mud Slu (N) upstrm of SLD Discharge	a	a	a	a	a	1.7	2.0	2.0	1.1	1.1	1.2	0.60	2.0
MER542	Mud Slu (N) dwnstrm of SLD Discharge	a	a	a	a	a	***3.4***	***5.1***	***6.3***	***4.9***	***5.1***	***5.4***	***6.2***	2.0
MER531	Salt Slough at Lander Avenue	a	a	a	a	a	1.1	1.3	0.52	0.36	0.27	0.39	0.45	2.0

= water quality objective exceedance

a = objective only applies 15 March through 15 September
WQO = water quality objective in mg/L

Table 12. Selenium Water Quality Objective Exceedances in the Grassland Watershed: Water Year 1998.

Station ID	Description	Mean Monthly Concentration (ug/L)												Monthly WQO
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
MER510	CCID Main Canal @ Russell	ND	ND	ND	ND	3.1	2.3	2.3	0.8	0.9	0.5	1	1.2	na
MER505	Camp 13 Ditch	0.9	1.2	***5.0***	1.4	***3.0***	***3.2***	***6.3***	1.3	1.8	0.9	1.7	1.1	2
MER506	Agatha Canal	0.8	1.3	***2.2***	1.3	***35.8***	***2.5***	***2.2***	1.1	0.7	0.5	1.3	1.2	2
MER532	San Luis Canal at Henry Miller Road	1.8	1.3	***2.6***	1.4	***8.2***	***4.2***	***2.6***	1.7	1.5	2.0	***2.3***	1.4	2
MER519	Santa Fe Canal at Henry Miller Road	1.5	1.1	1.6	1.2	***10.0***	***4.0***	***2.7***	1.8	1.2	1.3	1.7	1.5	2
MER563	San Luis Canal at Splits	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	***2.1***	1.4	2
MER545	Santa Fe Canal at Weir	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	***2.2***	1.8	2
MER551	Mud Slu (N) upstrm of SLD Discharge	0.6	0.5	0.6	0.5	0.9	1.2	1.0	1.4	1.3	1.5	1.6	1.1	5*
MER542	Mud Slu (N) dwnstrm of SLD Discharge	***12.1***	***7.9***	***6.9***	***8.6***	***7.2***	***20.5***	***52.2***	***67.3***	***43.0***	***31.4***	***33.1***	***29.1***	5*
MER531	Salt Slough at Lander Avenue	1.0	1.0	1.2	1.0	***4.0***	1.9	1.2	0.9	0.6	0.7	1.1	0.8	2

= water quality objective exceedance ND = no data available WQO = water quality objective in µg/L

****A compliance time schedule applies to the 5 ug/L 4-day average Se water quality objective in Mud Slough (north) until 1 October 2010.***

Table 13. Monthly Molybdenum Concentrations and Water Quality Objective Exceedances in the Grassland Watershed: Water Year 1998

Station ID	Description	Mean Monthly Concentration (ug/L)												Monthly WQO
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
MER536	Mud Slu (N) upstrm of SLD Discharge	7	6	9	4	3	3	17	12.5	4	5	5	5	19
MER535	San Luis Drain at the Terminus	44	48	38	36	7	16	26	28	ND	25	21	28	na
MER542	Mud Slu (N) dwnstrm of the SLD Discharge	19	12	15	7	3	6	***26***	***22***	16	14	15	15	19
MER531	Salt Slough at Lander Avenue	7	9	13	13	12	ND	7	3	ND	ND	3	ND	19

= water quality objective exceedance ND = no data available na = no water quality objective (WQO) for this site

(north) along with a compliance time schedule which requires that the objective be met by 1 October 2010.

During Water Year 1998, the 2.0 ug/L monthly mean selenium water quality objective was exceeded repeatedly in the supply channels (Camp 13, Agatha, San Luis Canal and Santa Fe Canal), and during February in Salt Slough. As discussed earlier, the primary cause of exceedances was the diversion of stormwater flood flows during February, flows which contained some subsurface agricultural drainage. However, a number of factors may have led to the additional exceedances and each must be further evaluated to determine a means of meeting the water quality objective. An initial study of additional sources of selenium into these water bodies was conducted and is available (Chilcott, 2000). Some potential sources identified include additional areas of subsurface agricultural drainage outside of the Drainage Project

Area, seepage from drainage channels, elevated concentrations in supply water, and natural background concentrations in local groundwater.

Although subject to the adopted compliance time schedule, selenium concentrations in Mud Slough (north) were evaluated against the 5 ug/L, 4-day average selenium water quality objective which will apply beginning 1 October 2010. Monthly mean selenium concentrations Mud Slough (north) downstream of the San Luis Drain Discharge continuously exceeded 5 ug/L during Water Year 1998, while monthly mean selenium concentrations remained below 2 ug/L upstream of the discharge.

Molybdenum

During Water Year 1998, molybdenum monitoring was focused on sites which would likely be influenced by the Grassland Bypass Project and included monthly analyses in Mud Slough (north) upstream and downstream of the San Luis Drain discharge, the San Luis Drain itself, and Salt Slough. Available data is presented in Table 13.

During Water Year 1998, molybdenum concentrations in Mud Slough (north) upstream of the San Luis Drain discharge and in Salt Slough resembled historic concentrations and did not exceed the 19 ug/L objective. While no objective applied to the drain itself, molybdenum concentrations in the discharge were elevated, ranging from 16 ug/L to 48 ug/L. This discharge did impact the water quality in the downstream segment of Mud Slough (north), elevating molybdenum concentrations over background (upstream) concentrations. The 19 ug/L molybdenum objective was exceeded on two separate occasions at the downstream location: during April and May.

LOADS OF SALT, BORON, AND SELENIUM

Monthly Loads, Water Year 1998

Water year 1998 was the second year of operation of the Grassland Bypass Project (GBP). Prior to water year 1997, discharge and load from the Drainage Project Area (DPA) was estimated by summing the discharge and load in several channels within the Grassland Watershed. Starting in water year 1997, all drainage from the DPA was diverted into the Grassland Bypass and the San Luis Drain as part of the GBP.

Salt, boron, and selenium loads for the GBP and the Grassland Watershed were estimated based upon the flow weighted monthly average of available water quality data for 1998. Discharge and electrical conductivity data for the GBP was obtained from the USBR (Nigel Quinn, personal communication). Daily discharge and daily electrical conductivity data for the two Grassland Watershed sites was obtained from the USGS (Henry Miyashita, personal communication). Salt loads for the GBP and the Grassland Watershed sites are based upon daily electrical conductivity measurements. Boron and selenium loads are based upon combined grab and automated Sigma^{tm} sample devices for the GBP. Only grab samples were collected and used for the Grassland Watershed sites. The methodology used to calculate loads can be found in Grober et al., 1998. Raw data used to present loads have been tabulated and are available in hard copy from the Regional Board's Sacramento office. This

information can also be found at the Regional Board web site. Follow the links to view or download files from:

http://www.swrcb.ca.gov/ ~rwqcb5

The tabulated flow and water quality data used to compute loads for water years 1986 through 1998 are presented at this website. Each year of data is comprised of four data tables; the first table contains mean daily flow data; the second, third and fourth contain electrical conductivity (EC), boron and selenium data, respectively. Additionally, EC, boron, and selenium data are presented for five Sigma™ automatic sampler sites for water years 1995 through 1998. Matrices are sparsely filled for some water quality data.

Monthly discharge and monthly flow weighted average concentrations and loads for the GBP were calculated for Water Year 1998 (Table 14). Loads for individual sites in the Drainage Project Area no longer need to be calculated to estimate total loads for the area because these discharges were consolidated into the San Luis Drain as part of the GBP in Water Year 1997. Monthly discharge and monthly flow weighted average concentrations and loads for the Grassland Watershed are based on the sum of discharge and loads for Mud Slough (north) and Salt Slough (Table 15).

Monthly discharge for the GBP ranged from 1 to 2 thousand acre-feet (taf) from September through January but increased dramatically in February due to much higher than average rainfall (Figure 10). Discharge remained high in March, slowly declining from a high of 7 taf in February to 3 taf in September. The pattern of discharge for Grassland Watershed was similar, with a sharp spike in February as a result of storm events. Discharge returned to pre-storm levels by April. The prolonged time period of higher discharge in the GBP compared to the Grassland Watershed as a whole is likely a function of elevated groundwater levels in the Drainage Project Area contributing to increased volumes of tile drainage.

The seasonal pattern of monthly salt and boron loads from these areas is similar to the pattern of discharge for both the GBP and Grassland Watershed (Figures 11 and 12). The key difference is that peak salt and boron loading for both areas occurred in March, rather than February. The GBP contributed up to 50 percent of the total salt load in the Grassland Watershed during the low flow months of June, July, and August, because discharge and loads from the GBP remained elevated while discharge and loads in the rest of the Grassland Watershed receded. The GBP contributed less than 25 percent of the total salt load of the Grassland Watershed during higher flow months of January and February. The GBP contributed from 25 to 80 percent of the boron loads to the Grassland Watershed, with the higher percentage occurring during the low flow summer months. Though the GBP contributes large quantities of salt and boron, it is not the only source of these constituents in the basin.

The GBP is, however, the primary source of selenium in the Grassland Watershed (Figure 13). In most months, the GBP accounted for more than 90 percent of the total selenium load in the Grassland Watershed. Note that the total selenium load attributable to the GBP is 350 pounds higher than indicated for February in Figure 13 and Table 14. This is the quantity of selenium attributable to GBP discharges that did not flow into the Grassland Bypass during February storm events. The total annual

Table 14. Monthly and Annual Discharge and Salt, Boron, and Selenium Loads and Flow Weighted Concentrations for the San Luis Drain for Water Year 1998

		Loads			Flow Weighted Concentration		
Month	Flow (taf)	Se (lbs)	B (1,000 lbs)	TDS (1,000 tons)	Se (ppb)	B (ppm)	TDS (ppm)
Oct	2	248	39	7	51.9	8.2	2,740
Nov	2	207	34	6	48.9	8.0	2,610
Dec	1	178	28	5	46.6	7.3	2,730
Jan	1	335	34	6	86.7	8.8	3,050
Feb*	7	965	100	20	50.8	5.3	2,110
Mar	7	1,600	160	29	82.8	8.3	2,970
Apr	6	1,550	130	24	103.1	8.7	3,260
May	5	1,370	110	23	103.0	8.3	3,410
Jun	4	807	79	14	81.6	8.0	2,840
Jul	5	615	95	15	49.5	7.6	2,490
Aug	4	500	79	13	47.4	7.5	2,470
Sep	3	388	56	10	44.7	6.5	2,350
WY Total	46	8,760	944	172	70.1	7.6	2,750

* Data presented does not includes stormwater flood flows and loads discharged to wetland channels in the Grassland Watershed in February, 1998

Table 15. Monthly and Annual Discharge and Salt, Boron, and Selenium Loads and Flow Weighted Concentrations for the Grassland Watershed for Water Year 1998

		Loads			Flow Weighted Concentration		
Month	Flow (taf)	Se (lbs)	B (1000 lbs)	TDS (1000 tons)	Se (ppb)	B (ppm)	TDS (ppm)
Oct	16	284	69	23	6.7	1.6	1,080
Nov	19	240	84	30	4.6	1.6	1,150
Dec	20	249	103	35	4.6	1.9	1,310
Jan	29	381	135	46	4.9	1.7	1,170
Feb	88	1,425	350	126	6.0	1.5	1,050
Mar	64	1,965	370	131	11.3	2.1	1,510
Apr	31	1,421	218	72	17.0	2.6	1,720
May	24	1,309	143	46	19.8	2.2	1,390
Jun	22	704	91	31	11.5	1.5	1,000
Jul	25	632	110	33	9.4	1.6	974
Aug	24	549	100	30	8.5	1.5	945
Sep	17	476	89	24	10.3	1.9	1,020
WY Total	378	9,630	1,860	626	9.4	1.8	1,220

selenium load attributable to the DPA was 9,110 pounds in 1998 (8,760 from the GBP plus 350 discharged to wetland channels). Total annual selenium load for the Grassland Watershed was 9,630 pounds. The DPA therefore contributed just under 95 percent of the total selenium load that left the Grassland Watershed in 1998. Calculated monthly selenium loads for the GBP are higher than the calculated monthly loads for the Grassland Watershed for April through June. Since all discharge and load from the GBP is included in the Grassland Watershed, this difference is due to losses in the system or an overestimate of loads from the GBP or underestimates for the Grassland Watershed. For a full discussion of possible calculation errors or system losses see Grober et al, 1998.

Annual Loads, Water Year 1986 to 1998

Annual discharges for the DPA and the Grassland Watershed sites for water years 1986 through 1998 are shown in Figure 14. Grassland Watershed discharge in Water Year 1998 was 25 percent higher than Water Years 1986 or 1997, previously the two wettest years on record for the 13-year period presented. Several years prior to Water Year 1998 had higher annual discharges from the DPA, however, including the wet years of 1986, 1995, and 1996. Salt loading from the Grassland Watershed was also the highest on record for the 13-year period (Figure 15). Salt loads were more than 20 percent higher in Water Year 1998 than in Water Years 1986, 1995, or 1996. As for discharge, this pattern was not repeated for the DPA; several years prior to Water Year 1998 had higher salt loads. Boron loads from the Grassland Watershed were at least 25 percent higher in Water Year 1998 than any prior year (Figure 16). Unlike salt and discharge, boron loads from the DPA were also higher than for any prior year, slightly exceeding loads discharged during Water Years 1987 and 1995. Selenium loads from the Grassland Watershed were the second highest on record, after Water Year 1995 (Figure 17). Selenium loads estimated for the DPA were higher in six of the twelve years prior to Water Year 1998.

High annual discharge and loading for the Grassland Watershed is attributable to high rainfall in the watershed that started in February and continued intermittently through May. Some of the trends evident for discharge and the various salts from the DPA and Grassland Watershed can be further explained based on what is known about the changing hydrology and management of the DPA over the last few years. With the advent of the GBP and use of the San Luis Drain to route agricultural drainage from the DPA to Mud Slough (north), new management practices have had an influence on water quality from the DPA. The Grassland Area Farmers (GAF's) have greatly restricted the quantity of tail water that is commingled with subsurface tile drainage. The GAF's have also used selective recycling and blending of tile drainage with agricultural supply water and other water conservation and drainage reduction methods to reducing peak selenium loads.

Water conservation and tailwater reduction have likely contributed to the overall reduction in drainage volume discharged from the DPA in recent wet years relative to prior wet years. This reduction in drainage volume has occurred at time when total discharge from the Grassland Watershed has actually increased to the highest levels seen in the last 13 years. Water conservation and tailwater reduction does not seem to have resulted in an increase in concentration for all salts. The mean annual concentration of selenium in discharge from the DPA was 70 ug/L in Water Year 1998, similar to the two preceding wet years. The mean annual TDS concentration of 2,750 mg/L was also similar to the two preceding years. The mean annual boron concentration of 7.6 mg/L was, however, the highest on record in the last 13 years. The mean annual boron concentration was 5.0 and 7.1, respectively, in Water Years 1996 and 1997.

Reduction in drainage volume from the DPA has resulted in reduction of salt load as well, relative to other wet years. Water years 1986, 1995, and 1996 each had higher drainage volumes and salt loads from the DPA than 1998. Some of the reduced salt load is due to decreased load from tailwater, which has been mostly eliminated from the GBP in the last 3 years. Similar decreases in selenium and boron loads are not likely to occur as a result of tailwater elimination because most selenium and boron in this area are associated with tile drainage. The dramatic reduction in selenium loading from the DPA, compared to prior wet years, is likely due to other factors such as selective recycling of tile drainage with high selenium concentrations. Selenium loads in Water Year 1998 were lower than for several years with higher discharge, including 1986, 1987, 1988, 1995, and 1996. The same trend is not, however, evident for boron loading. Water Year 1998 boron loads are higher than any prior year. This different pattern of selenium and boron loading may have occurred because management decisions made to limit selenium loads discharged from the DPA do not necessarily have a similar impact on boron loads. Subsurface drainage selected for recycling and blending because of its high selenium concentrations may not have similarly high boron concentrations. If this is the case, boron loads may remain elevated or increase while selenium loads decrease. Loads of salt, boron, and selenium will have to be monitored for several more years at the current hydrologic and management conditions to fully understand the patterns of salt, boron, and selenium loading.

Figure 10. Monthly Discharge from the Grassland Bypass and Grassland Watershed, Water Years 1998

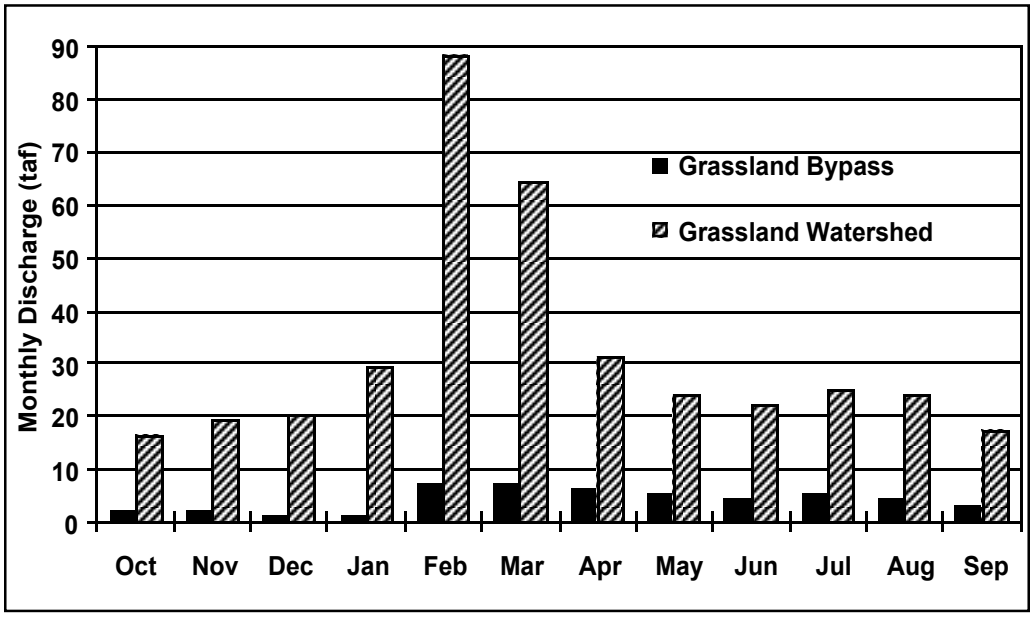


Figure 11. Monthly Salt Loads from the Grassland Bypass and Grassland Watershed, Water Years 1998

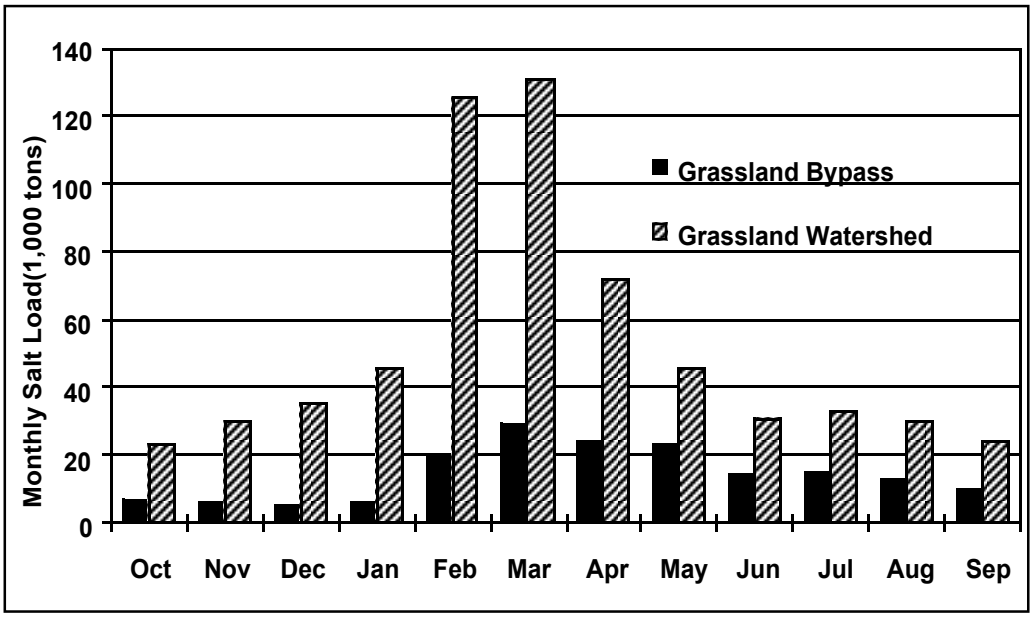


Figure 12. Monthly Boron Loads from the Grassland Bypass and Grassland Watershed, Water Years 1998

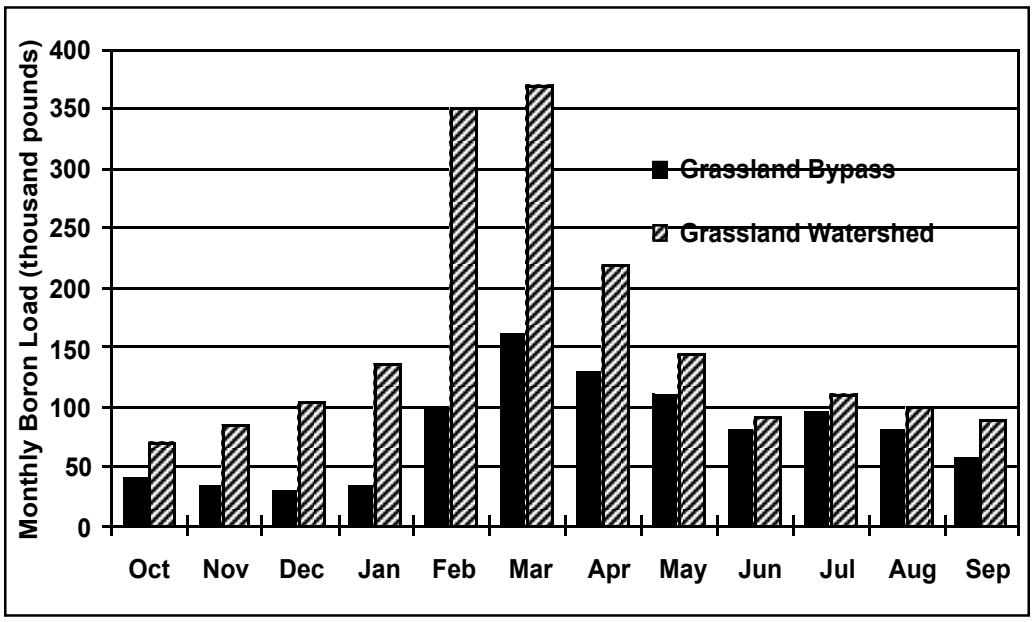


Figure 13. Monthly Selenium Loads from the Grassland Bypass and Grassland Watershed, Water Years 1998

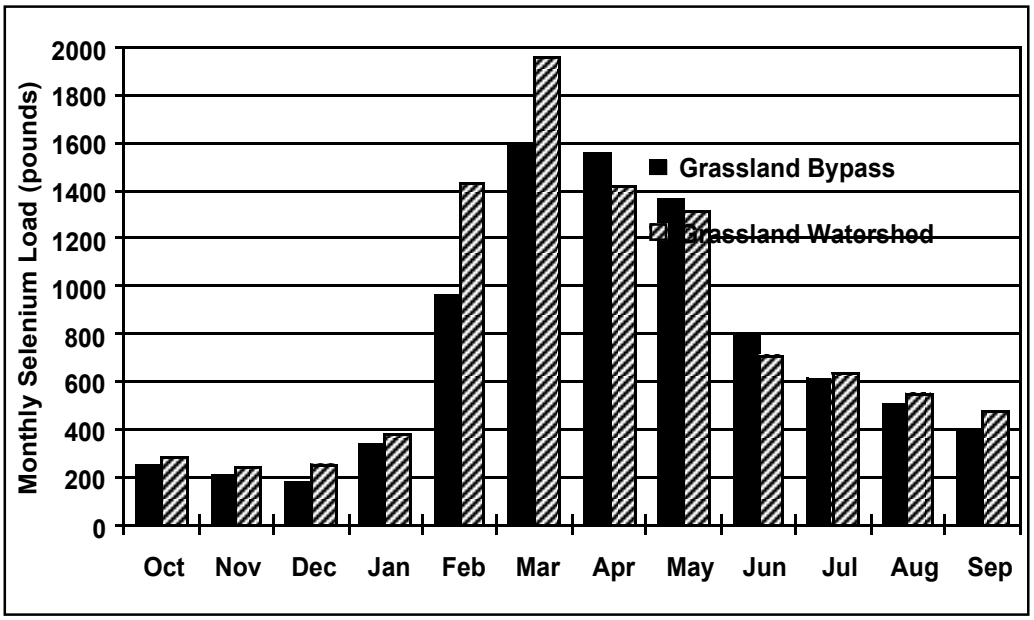


Figure 14. Annual Discharge from the Drainage Project Area and the Grassland Watershed, Water Years 1986 through 1998

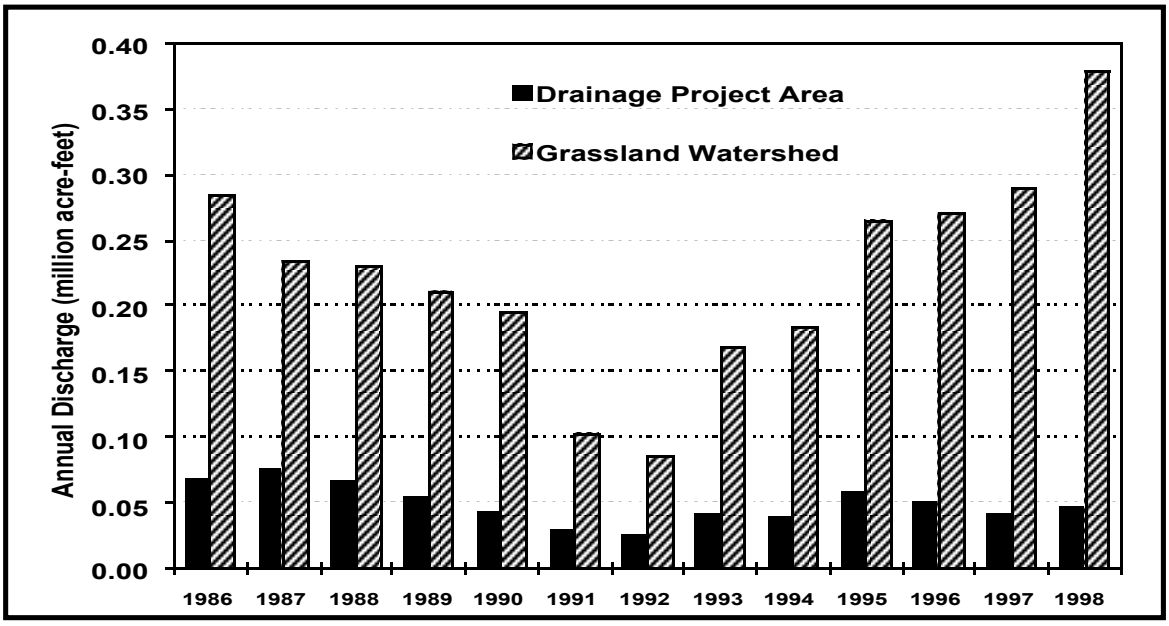


Figure 15. Annual Salt Load from the Drainage Project Area and the Grassland Watershed, Water Years 1986 through 1998

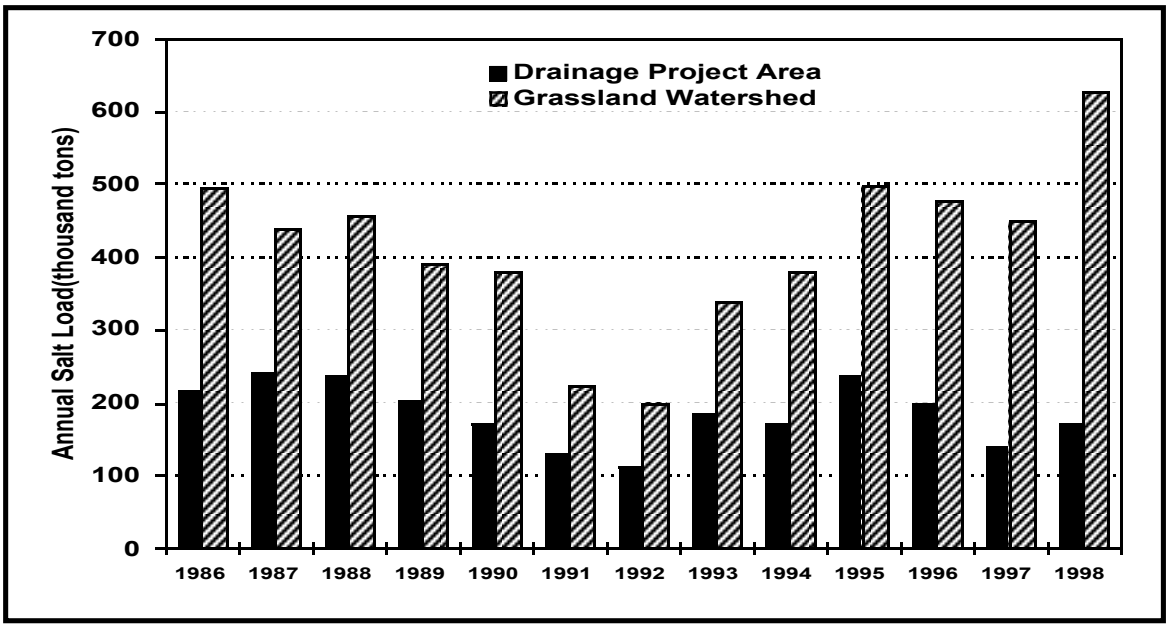


Figure 16. Annual Boron Load from the Drainage Project Area and the Grassland Watershed, Water Years 1986 through 1998

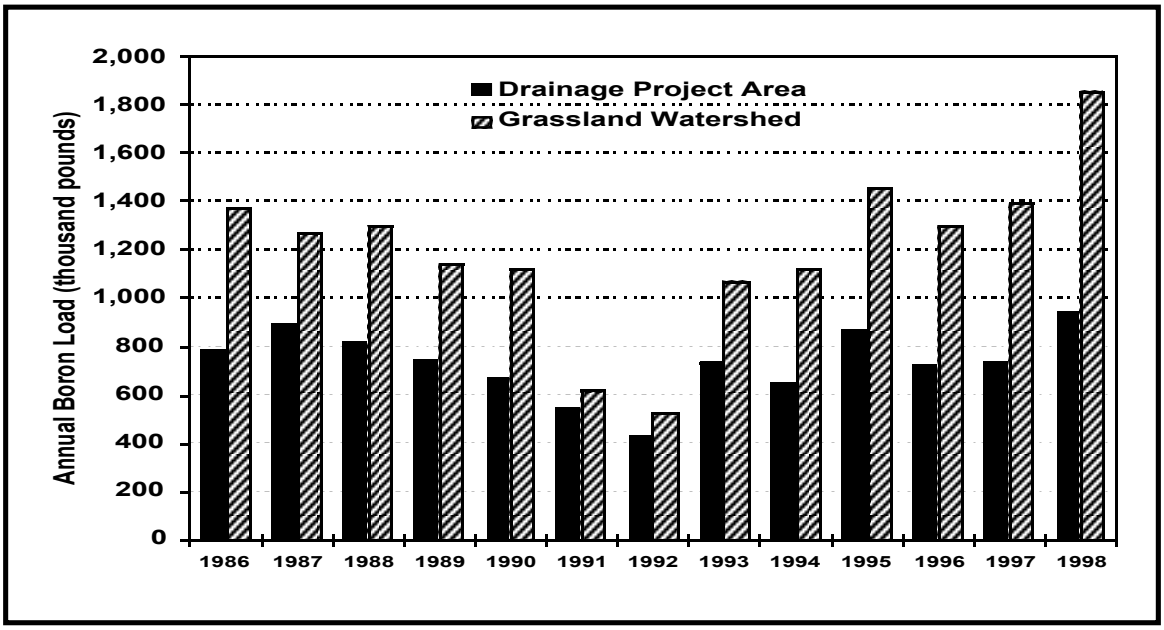
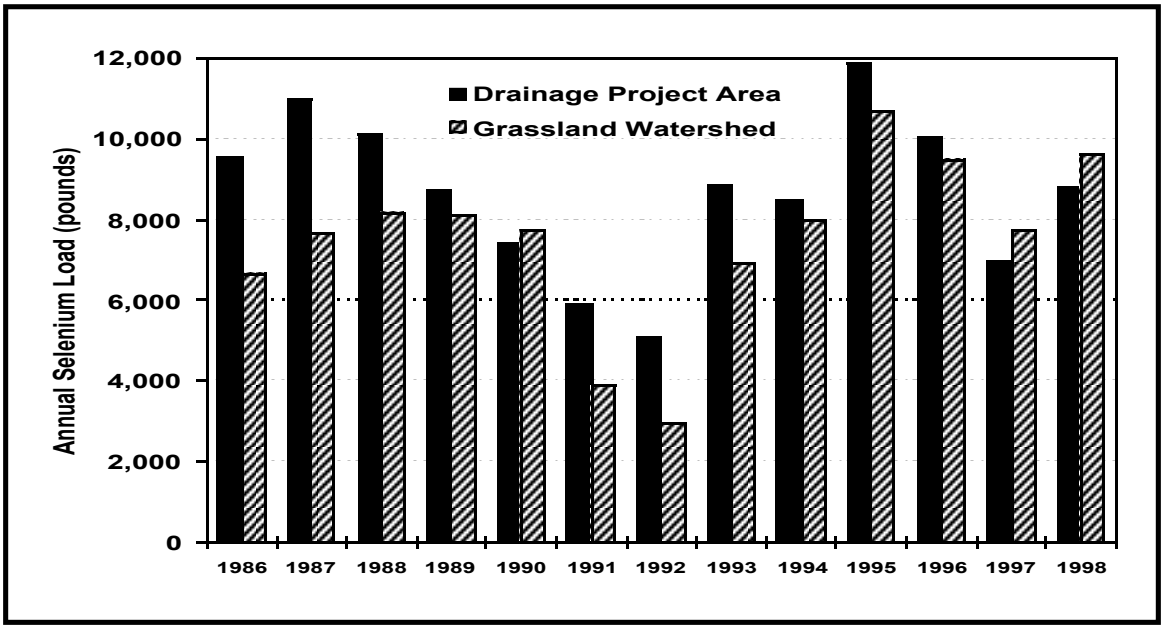


Figure 17. Annual Selenium Load from the Drainage Project Area and the Grassland Watershed, Water Years 1986 through 1998



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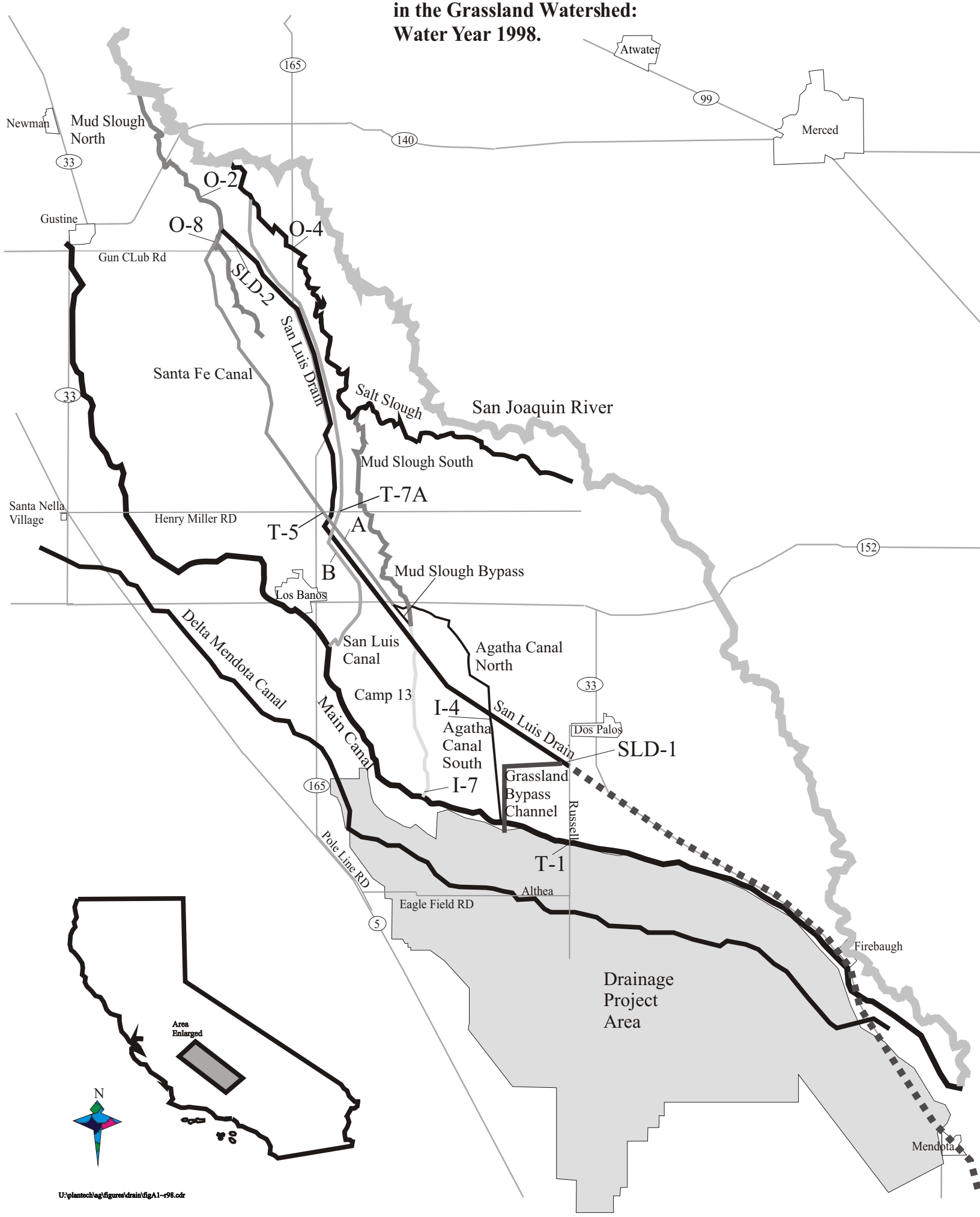
APPENDIX A

Water Quality Data for Grab Samples: Water Year 1998

Legend of Abbreviations

EC	Electrical Conductivity
Se	Selenium
Mo	Molybdenum
Cr	Chromium
Cu	Copper
Ni	Nickel
Pb	Lead
Zn	Zinc
B	Boron
Cl	Chlorine
SO4	Sulfate
HDNS	Hardness

Figure A-1. Water Quality Sampling Locations in the Grassland Watershed: Water Year 1998.



Agatha Canal at Mallard Road (MER506)

Location: Latitude: 36°56'12", Longitude 120°42'07". In NE 1/4, NW 1/4, SW 1/4, Sec. 7, T.11S., R.11E
South of Sante Fe Grade at Brito, west of Mallard Road. 4.5 miles west of Dos Palos.

Date	Time	Temp F	pH	EC umhos/cm	Se ug/L	B .mg/L	Cl mg/L	SO4 mg/L	HDNS mg/L	Ca mg/L	Mg mg/L
10/1/97	1245	NA	NA	428	0.9	0.18					
10/8/97	1250	NA	NA	539	0.8	0.25					
10/15/97	1240	NA	NA	539	0.7	0.24					
10/22/97	1055	NA	NA	466	0.8	0.23					
10/29/97	NA	NA	NA	532	1.0	0.24					
11/5/97	1250	NA	NA	634	0.7	0.24					
11/12/97	1240	NA	NA	758	0.9	0.40					
11/19/97	1240	NA	NA	623	1.8	0.46					
11/25/97	0921	NA	NA	629	1.7	0.39					
12/3/97	1320	NA	NA	631	1.9	0.48					
12/10/97	0950	NA	NA	664	0.9	0.46					
12/17/97	1245	NA	NA	765	1.5	0.75					
12/23/97	1240	NA	NA	948	0.9	0.92					
12/30/97	1100	NA	NA	1080	5.9	0.77					
1/7/98	1300	NA	NA	830	0.7	0.44					
1/14/98	1240	NA	NA	1040	1.2	1.2					
1/21/98	1420	NA	NA	1660	1.6	2.8					
1/28/98	1130	NA	NA	2270	1.5	3.6					
2/4/98	1300	NA	NA	2450	27.0	3.5					
2/11/98	1150	NA	NA	2940	39.2	3.3					
2/18/98	1330	NA	NA	3030	36.4	4.3					
2/25/98	1130	NA	NA	3370	40.4	5.9					
3/4/98	1155	NA	NA	2750	3.5	6.1					
3/11/98	1235	NA	NA	799	3.9	0.86					
3/18/98	1150	NA	NA	997	1.1	1.7					
3/25/98	1150	NA	NA	593	1.5	0.93					
4/1/98	1135	NA	NA	NA	2.8	1.7					
4/8/98	1250	NA	NA	2140	1.8	4.6					
4/15/98	1300	NA	NA	2670	2.2	5.2					
4/22/98	1245	NA	NA	2690	2.3	5.1					
4/29/98	1245	NA	NA	256	1.9	4.8					
5/6/98	1145	NA	NA	413	1.4	0.56					
5/13/98	1315	NA	NA	606	1.0	1.2					
5/20/98	1245	NA	NA	468	0.9	0.68					
5/27/98	1300	NA	NA	172	1.0	0.18					
6/3/98	1340	NA	NA	101	0.7	0.07					
6/10/98	1250	NA	NA	97	0.7	0.12					
6/17/98	1200	NA	NA	112	0.6	0.07					
6/24/98	1235	NA	NA	144	0.6	0.09					
7/1/98	1200	NA	NA	68	<0.4	<0.05					
7/8/98	1240	NA	NA	80	<0.4	<0.05					
7/15/98	1155	NA	NA	66	<0.4	<0.05					
7/22/98	1250	NA	NA	158	0.4	0.18					
7/29/98	1400	NA	NA	198	1.5	0.18					
8/5/98	1245	NA	NA	350	1.4	0.31					
8/12/98	1150	NA	NA	486	1.3	0.46					
8/19/98	1145	NA	NA	326	1.1	0.22					
8/26/98	1335	NA	NA	359	1.2	0.24					
9/2/98	1315	NA	NA	392	1.2	0.24					
9/9/98	1345	NA	NA	339	1.5	0.22					
9/16/98	1100	NA	NA	278	1.1	0.16					
9/23/98	1310	NA	NA	300	1.5	0.17					
9/30/98	1325	NA	NA	270	0.7	0.14					
Count				52	53	53					
Min				66	<0.4	<0.05					
Max				3370	40.4	6.1					
Mean				875	4.0	1.3					
Geo Mean				531	1.4	0.49					
Median				539	1.2	0.44					

Camp 13 Slough at Gauge Station (MER505)

Location: Latitude 36°56'21", Longitude 120∞45'22". In SE 1/4, SE 1/4, SW 1/4, Sec. 27, T.11S., R.11E. 150 feet north CCID Main Canal, 6.4 miles west of Russel Avenue. 9.2 miles SE of Los Banos. 6.7 miles SW of South Dos Palos

Date	Time	Temp ₣	pH	EC umhos/cm	Se ug/L	B mg/L	Cl mg/L	SO4 mg/L	HDNS mg/L	Ca mg/L	Mg mg/L
10/1/97	1030	NA	NA	462	1.0	0.19					
10/8/97	1036	NA	NA	569	1.1	0.29					
10/15/97	1030	NA	NA	523	1.0	0.30					
10/22/97	0802	NA	NA	524	0.8	0.23					
10/29/97	NA	NA	NA	577	0.8	0.26					
11/5/97	1020	NA	NA	673	0.8	0.29					
11/12/97	1033	NA	NA	728	0.7	0.33					
11/19/97	1015	NA	NA	833	1.6	0.77					
11/25/97	0745	NA	NA	807	1.6	0.76					
12/3/97	0800	NA	NA	1220	8.4	1.4					
12/10/97	0740	NA	NA	1470	5.2	1.8					
12/17/97	0740	NA	NA	2890	8.9	4.5					
12/23/97	0730	NA	NA	6530	1.6	13					
12/30/97	0730	NA	NA	1080	0.8	1.0					
1/7/98	0740	NA	NA	1110	1.0	1.2					
1/14/98	0735	NA	NA	1140	1.2	1.1					
1/21/98	0850	NA	NA	2050	1.7	11					
1/28/98	0740	NA	NA	6610	1.6	12					
2/4/98	0800	NA	NA	1420	2.8	3.1					
2/11/98	1030	NA	NA	2420	4.0	4.2					
2/18/98	0800	NA	NA	2370	3.3	4.4					
2/25/98	0730	NA	NA	2250	1.8	4.9					
3/4/98	0900	NA	NA	3980	3.4	7.7					
3/11/98	0910	NA	NA	1210	4.0	1.6					
3/18/98	0920	NA	NA	4690	3.5	9.4					
3/25/98	0800	NA	NA	2340	1.7	3.9					
4/1/98	0800	NA	NA	NA	11.5	12					
4/8/98	0845	NA	NA	4470	9.8	7.3					
4/15/98	0740	NA	NA	6270	7.3	12					
4/22/98	0905	NA	NA	245	1.7	0.22					
4/29/98	0800	NA	NA	209	1.1	0.17					
5/6/98	0800	NA	NA	841	1.6	1.7					
5/13/98	0800	NA	NA	1460	1.6	2.8					
5/20/98	0800	NA	NA	295	1.3	0.37					
5/27/98	0800	NA	NA	147	0.8	0.12					
6/3/98	0800	NA	NA	209	1.7	0.21					
6/10/98	0900	NA	NA	4100	2.5	6.9					
6/17/98	0800	NA	NA	217	1.8	0.26					
6/24/98	0745	NA	NA	142	1.0	0.15					
7/1/98	0740	NA	NA	100	0.7	0.08					
7/8/98	0740	NA	NA	64	<0.4	<0.05					
7/15/98	0740	NA	NA	158	<0.4	0.18					
7/22/98	0740	NA	NA	301	2.6	0.58					
7/29/98	0740	NA	NA	328	1.0	0.37					
8/5/98	0800	NA	NA	464	1.3	0.51					
8/12/98	0740	NA	NA	NA	2.0	0.65					
8/19/98	0745	NA	NA	590	2.1	0.90					
8/26/98	0745	NA	NA	444	1.3	0.31					
9/2/98	0745	NA	NA	271	1.1	0.17					
9/9/98	0745	NA	NA	283	1.5	0.23					
9/16/98	0745	NA	NA	315	1.0	0.23					
9/23/98	0750	NA	NA	253	1.1	0.15					
9/30/98	0740	NA	NA	278	0.7	0.14					
Count				51	53	52					
Min				64	<0.4	<0.05					
Max				6610	11.5	13					
Mean				1430	2.4	2.6					
Geo Mean				747	1.6	0.84					
Median				673	1.6	0.65					

CCID Main @ Russell Avenue (MER510)

Location: Latitude 36°55'28", Longitude 120°39'11". In SE 1/4, SE 1/4, SW 1/4, Sec. 33, T.11S., R.12E
2.7 miles south of Dos Palos

Date	Time	Temp °F	pH	EC umhos/cm	Se ug/L	B mg/L	Cl mg/L	SO4 mg/L	HDNS mg/L	Ca mg/L	Mg mg/L
2/4/98	11:30	NA	NA	1000	3.1	1.1					
2/11/98	9:00	NA	NA	978	3.6	1.1					
2/18/98	13:25	NA	NA	748	2.8	0.53					
2/25/98	9:30	NA	NA	428	2.8	0.26					
3/4/98	10:30	NA	NA	411	3.9	0.33					
3/11/98	10:20	NA	NA	467	2.4	0.27					
3/18/98	9:45	NA	NA	2500*	1.4	0.15					
3/25/98	10:00	NA	NA	260	1.5	NA					
4/1/98	9:30	NA	NA	NA	3.6	0.31					
4/8/98	11:40	NA	NA	386	3.4	0.48					
4/15/98	10:00	NA	NA	280	2.2	0.20					
4/22/98	10:45	NA	NA	183	1.1	0.09					
4/29/98	10:00	NA	NA	145	1.0	0.08					
5/6/98	9:40	NA	NA	161	1.3	0.09					
5/13/98	10:00	NA	NA	157	0.8	0.08					
5/20/98	10:00	NA	NA	110	0.6	0.09					
5/27/98	10:00	NA	NA	127	0.6	0.05					
6/3/98	10:00	NA	NA	91	0.7	<0.05					
6/10/98	9:50	NA	NA	94	0.6	<0.05					
6/17/98	9:50	NA	NA	79	1.1	0.06					
6/24/98	9:40	NA	NA	69	1.1	0.07					
7/1/98	9:30	NA	NA	52	<0.4	<0.05					
7/8/98	10:40	NA	NA	76	<0.4	<0.05					
7/15/98	10:30	NA	NA	43	<0.4	<0.05					
7/22/98	10:30	NA	NA	116	0.9	0.43					
7/29/98	10:30	NA	NA	155	0.8	0.11					
8/5/98	10:30	NA	NA	298	1.2	0.19					
8/12/98	9:20	NA	NA	269	0.9	0.16					
8/19/98	10:40	NA	NA	350	1.0	0.21					
8/26/98	11:00	NA	NA	216	0.8	0.15					
9/2/98	10:50	NA	NA	293	1.1	0.17					
9/9/98	11:10	NA	NA	265	0.9	0.17					
9/16/98	10:00	NA	NA	309	1.2	0.19					
9/23/98	10:40	NA	NA	283	1.7	0.18					
9/30/98	10:00	NA	NA	303	1.3	0.17					
* Data suspected to be erroneous											
Count				33	35	34					
Min				43	<0.4	<0.05					
Max				1000	3.9	1.1					
Mean				279	1.5	0.22					
Geo Mean				207	1.1	0.14					
Median				260	1.1	0.17					

Santa Fe Canal at Henry Miller Road (MER519)

Location: Latitude 37°05'59", Longitude 120°49'44". In NE 1/4, NE 1/4, Sec. 1, T.10S., R.10E. 0.3 mile east of Lander Avenue. 3.0 miles north of Gustine.

Date	Time	Temp F	pH	EC umhos/cm	Se ug/L	B mg/L	Cl mg/L	SO4 mg/L	HDNS mg/L	Ca mg/L	Mg mg/L
10/1/97	1340	NA	NA	522	2.0	0.34					
10/8/97	1330	NA	NA	690	1.3	0.62					
10/15/97	1345	NA	NA	852	1.6	0.79					
10/22/97	1125	NA	NA	998	1.3	1.1					
10/29/97	NA	NA	NA	987	1.1	1.0					
11/5/97	1345	NA	NA	970	0.9	0.89					
11/12/97	1340	NA	NA	1100	1.1	1.4					
11/19/97	1330	NA	NA	1200	1.1	1.4					
11/25/97	0955	NA	NA	1390	1.1	1.7					
12/3/97	1410	NA	NA	1350	2.9	1.7					
12/10/97	1430	NA	NA	1710	1.2	2.5					
12/17/97	1355	NA	NA	1860	1.1	2.8					
12/23/97	1350	NA	NA	2130	1.4	3.1					
12/30/97	1200	NA	NA	2410	1.3	3.4					
1/7/98	1400	NA	NA	1570	1.0	1.7					
1/14/98	1420	NA	NA	1810	1.4	2.3					
1/21/98	1440	NA	NA	5550*	0.9	2.7					
1/28/98	1300	NA	NA	2020	1.3	2.6					
2/4/98	1420	NA	NA	1550	7.3	2.2					
2/11/98	1350	NA	NA	2350	13.0	3.0					
2/18/98	1420	NA	NA	2400	11.6	3.3					
2/25/98	1235	NA	NA	2020	8.0	3.0					
3/4/98	1300	NA	NA	2420	3.6	2.4					
3/11/98	1330	NA	NA	2170	5.4	2.9					
3/18/98	1300	NA	NA	2260	4.1	3.2					
3/25/98	1300	NA	NA	1950	2.8	2.9					
4/1/98	1300	NA	NA	NA	3.3	4.2					
4/8/98	1420	NA	NA	1870	3.4	2.9					
4/15/98	1310	NA	NA	1980	3.1	2.7					
4/22/98	1330	NA	NA	1030	1.8	1.1					
4/29/98	1340	NA	NA	681	1.7	0.81					
5/6/98	1230	NA	NA	564	1.6	0.65					
5/13/98	1345	NA	NA	903	1.5	1.3					
5/20/98	1330	NA	NA	982	1.9	1.2					
5/27/98	1330	NA	NA	922	2.0	1.1					
6/3/98	1400	NA	NA	415	1.2	0.47					
6/10/98	1330	NA	NA	430	1.0	0.45					
6/17/98	1245	NA	NA	465	1.2	0.56					
6/24/98	1310	NA	NA	507	1.2	0.67					
7/1/98	1250	NA	NA	451	1.1	0.55					
7/8/98	1315	NA	NA	363	0.7	0.41					
7/15/98	1316	NA	NA	518	1.1	0.56					
7/22/98	1320	NA	NA	517	1.5	0.58					
7/29/98	1430	NA	NA	564	1.9	0.70					
8/5/98	1315	NA	NA	564	2.1	0.56					
8/12/98	1248	NA	NA	591	1.6	0.60					
8/19/98	1345	NA	NA	868	1.8	0.93					
8/26/98	1400	NA	NA	524	1.4	0.51					
9/2/98	1350	NA	NA	646	1.8	0.61					
9/9/98	1420	NA	NA	484	1.7	0.39					
9/16/98	1215	NA	NA	368	1.2	0.29					
9/23/98	1350	NA	NA	373	1.6	0.29					
9/30/98	1400	NA	NA	341	1.1	0.20					
* Data suspected to be erroneous											
Count				51	53	53					
Min				341	0.7	0.20					
Max				2420	13.0	4.2					
Mean				1149	2.4	1.5					
Geo Mean				951	1.8	1.1					
Median				970	1.5	1.1					

San Luis Canal at Henry Miller Road (MER532)

Location: Latitude 37° 06' 00" Longitude 120° 49' 13". In SE 1/4, SW 1/4, SE 1/4, Section 36, T10s, R10E. The site is 3 miles northeast of Los Banos at the Los Banos Wildlife Refuge.

Date	Time	Temp ℉	pH	EC umhos/cm	Se ug/L	B -mg/L	Cl mg/L	SO4 mg/L	HDNS mg/L	Ca mg/L	Mg mg/L
10/1/97	1315	NA	NA	520	1.9	0.33					
10/8/97	1315	NA	NA	660	1.7	0.53					
10/15/97	1325	NA	NA	837	2.1	0.67					
10/22/97	1120	NA	NA	671	2.0	0.41					
10/29/97	NA	NA	NA	550	1.1	0.33					
11/5/97	1320	NA	NA	772	0.8	0.44					
11/12/97	1320	NA	NA	806	1.1	0.55					
11/19/97	1316	NA	NA	788	1.4	0.63					
11/25/97	0950	NA	NA	674	2.0	0.40					
12/3/97	1350	NA	NA	1220	7.2	1.2					
12/10/97	1415	NA	NA	1700	2.0	2.5					
12/17/97	1330	NA	NA	1880	1.3	2.8					
12/23/97	1330	NA	NA	2170	1.4	3.1					
12/30/97	1145	NA	NA	2320	1.2	3.3					
1/7/98	1345	NA	NA	1200	1.0	1.0					
1/14/98	1400	NA	NA	1010	1.8	1.0					
1/21/98	1430	NA	NA	1720	1.4	2.0					
1/28/98	1245	NA	NA	1520	1.5	1.7					
2/4/98	1410	NA	NA	1230	5.1	1.5					
2/11/98	1310	NA	NA	2260	8.3	2.8					
2/18/98	1410	NA	NA	2190	8.9	3.0					
2/25/98	1300	NA	NA	2310	10.5	3.6					
3/4/98	1330	NA	NA	1830	4.0	3.4					
3/11/98	1350	NA	NA	2150	5.4	2.9					
3/18/98	1320	NA	NA	2340	4.3	3.4					
3/25/98	1330	NA	NA	1990	3.0	2.8					
4/1/98	1330	NA	NA	NA	3.2	4.3					
4/8/98	1430	NA	NA	2560	3.3	4.5					
4/15/98	1330	NA	NA	2410	3.4	3.3					
4/22/98	1345	NA	NA	1570	1.8	2.1					
4/29/98	1350	NA	NA	1290	1.4	1.8					
5/6/98	1245	NA	NA	1280	1.8	2.0					
5/13/98	1400	NA	NA	1520	2.0	2.1					
5/20/98	1345	NA	NA	1490	1.5	1.8					
5/27/98	1345	NA	NA	877	1.6	NA					
6/3/98	1410	NA	NA	577	1.5	0.68					
6/10/98	1345	NA	NA	1230	1.5	1.8					
6/17/98	1300	NA	NA	805	1.4	1.2					
6/24/98	1330	NA	NA	692	1.6	0.99					
7/1/98	1320	NA	NA	709	1.7	1.0					
7/8/98	1330	NA	NA	687	1.6	1.1					
7/15/98	1340	NA	NA	739	1.6	1.0					
7/22/98	1330	NA	NA	998	2.6	1.7					
7/29/98	1445	NA	NA	876	2.5	1.6					
8/5/98	1330	NA	NA	727	2.2	0.93					
8/12/98	1243	NA	NA	706	2.0	0.89					
8/19/98	1400	NA	NA	1350	3.0	2.3					
8/26/98	1410	NA	NA	648	1.8	0.77					
9/2/98	1355	NA	NA	557	1.5	0.47					
9/9/98	1425	NA	NA	498	1.9	0.42					
9/16/98	1220	NA	NA	404	1.2	0.35					
9/23/98	1400	NA	NA	396	1.4	0.33					
9/30/98	1410	NA	NA	350	1.1	0.24					
* Data suspected to be erroneous											
Count				52	53	52					
Min				350	0.8	0.24					
Max				2560	10.5	4.5					
Mean				1217	2.5	1.7					
Geo Mean				1054	2.1	1.2					
Median				1004	1.8	1.4					

Santa Fe Canal at weir (MER545)
Location: Latitude 37°05'55", Longitude 120°49'36". In NE 1/4, NE 1/4, Sec. 1, T.10S., R.10E. 0.3 mile east of Lander Avenue. 3.0 miles north of Gustine.

Date	Time	Temp °F	pH	EC umhos/cm	Se ug/L	B mg/L	Cl mg/L	SO4 mg/L	HDNS mg/L	Ca mg/L	Mg mg/L
8/12/98		NA	NA	1000	2.3	1.70					
8/19/98		NA	NA	1710	1.7						
8/26/98	1355	NA	NA	955	2.5	1.60					
9/2/98	1340	NA	NA	1100	2.6						
9/9/98	1410	NA	NA	545	2.7	0.47					
9/16/98	1210	NA	NA	437	1.2	0.40					
9/23/98	1335	NA	NA	426	1.2	0.35					
9/30/98	1345	NA	NA	356	1.1	0.26					
Count				8	8	6					
Min				356	1.1	0.26					
Max				1710	2.7	1.70					
Mean				816	1.9	0.80					
Geo Mean				710	1.8	0.60					
Median				750	2.0	0.44					

San Luis Canal at splits (MER563)
Location: Latitude 37° 05' 53" Longitude 120° 79' 38". In SE 1/4, SW 1/4, SE 1/4, Section 36, T10s, R10E. The site is 3 miles northeast of Los Banos at the Los Banos Wildlife Refuge.

Date	Time	Temp °F	pH	EC umhos/cm	Se ug/L	B mg/L	Cl mg/L	SO4 mg/L	HDNS mg/L	Ca mg/L	Mg mg/L
8/12/98		NA	NA	599	1.6	0.61					
8/19/98		NA	NA	719	3.3						
8/26/98	1350	NA	NA	465	1.5	0.38					
9/2/98	1345	NA	NA	494	1.4	0.36					
9/9/98	1415	NA	NA	470	1.4	0.37					
9/16/98	1207	NA	NA	359	1.2	0.28					
9/23/98	1345	NA	NA	368	1.6	0.28					
9/30/98	1355	NA	NA	339	1.0	0.19					
Count				8	8	7					
Min				339	1.0	0.19					
Max				719	3.3	0.61					
Mean				477	1.6	0.35					
Geo Mean				462	1.5	0.33					
Median				468	1.5	0.36					

Mud Slough (north) at San Luis Drain (MER542)

Location: Latitude 37°19'50", Longitude 120°57"03". In NW 1/4, NE 1/4, NW 1/4, Sec. 14, T.7S., R.9E. 5.0 miles east of Gustine, 3.5 miles SE of Highway 140. Located within Kesterson N. W. R.

Date	Time	Temp ℉	pH	EC umhos/cm	Se	Mo	Cr	Cu	Ni	Pb	Zn	B	Cl	SO4	HDNS	Ca	Mg
					ug/L							mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
10/2/97	1231	76	8.1	1820	11.0							2.2					
10/9/97	1010	63	8.0	1860	12.6							2.5					
10/16/97	1215	70	8.0	1960	10.2							2.5					
10/24/97	0805	60	7.9	2050	11.4							2.5					
10/30/97	0830	60	7.1	2400	15.4	19	3.1	4.1	8.5	<5	13	3.1	300	610	520	NA	NA
11/6/97	1000	65	8.0	2340	9.2							3.1					
11/14/97	1425	61	7.8	1900	8.6							2.2					
11/19/97	1955	60	8.0	1820	7.3							2.0					
11/25/97	1245	65	7.9	2070	6.6	12						2.3					
12/5/97	1210	56	8.4	2030	6.1							2.4					
12/11/97	1105	49	7.8	1970	9.1							2.1					
12/18/97	1400	53	7.8	1890	3.2							1.9					
12/26/97	1120	47	8.0	2430	9.0	15						2.7					
1/2/98	1220	56	7.5	2970	13.1							3.3					
1/8/98	1355	54	8.3	2610	12.1							2.9					
1/15/98	1330	52	7.5	1730	8.1							1.9					
1/22/98	1145	52	8.1	1100	3.1							1.1					
1/29/98	0850	57	7.8	1790	6.6	7	13	10	18	<5	NA	2.0	220	340	380	77	47
2/5/98	0930	54	7.8	1190	6.4							1.4					
2/11/98	1515		7.4	1100	5.7							1.2					
2/19/98	1215	56	7.7	1270	8.0							1.5					
2/26/98	0845	56	7.8	1340	8.7	3						1.5					
3/5/98	1305	55	8.0	1850	13.8							2.3					
3/12/98	1225	62	8.1	2280	19.5							2.8					
3/19/98	1720	72	8.2	2900	24.6							3.6					
3/26/98	1200	64	7.5	2540	24.0	6						3.3					
4/2/98	1130	58	8.0	2360	21.8							3.1					
4/9/98	1020	62	8.1	2660	26.6							3.5					
4/16/98	0715	59	8.2	3630	46.0							4.6					
4/23/98	1210	72	8.2	4690	70.0							6.7					
4/30/98	0920	74	8.0	5240	96.8	26						7.4					
5/7/98	1135	68	7.8	3150	38.3							3.9					
5/14/98	0935	61	7.6	4070	53.3	20	13	5.4	13	<5	NA	5.5	480	1200	960	240	87
5/21/98	1035	69	8.2	4620	73.6							6.8					
5/28/98	1331	62	8.3	5340	104	24						8.9					
6/4/98	1105	71	8.2	2870	32.8							4.1					
6/11/98	1315	70	8.2	2690	38.6							3.8					
6/18/98	1010	78	8.2	3780	61.4							5.8					
6/25/98	1200	80	8.2	3480	39.0	16	7.9	3.8	9.2	<5	NA	5.7	440	1100	830	210	74
7/2/98	1010	77	8.2	3060	30.5							4.8					
7/9/98	1150	84	7.8	3270	30.5							5.2					
7/16/98	1155	85	7.8	3650	37.0							5.9					
7/23/98	1215	82	8.0	2880	30.1							4.6					
7/30/98	1155	82	7.8	3120	29.0	14						5.0					
8/6/98	1205	86	8.1	3170	30.2							5.0					
8/12/98	1605	86	8.3	3330	33.5							5.3					
8/20/98	1300	76	7.8	3230	30.8							5.2					
8/27/98	1135	77	7.9	3740	37.8	15						6.1					
9/3/98	0920	81	7.7	3590	37.8							5.9					
9/10/98	1045	74	7.3	3790	35.4							6.5					
9/17/98	1040	78	7.2	2870	31.8							4.5					
9/24/98	1155	NA	NA	1800	11.5	15						2.6					
Count		50	51	52	52	13	4	4	4	4	1	52	4	4	4	3	3
Min		47	7.1	1100	3.1	3	3.1	3.8	8.5	<5	13	1.1	220	340	380	77	47
Max		86	8.4	5340	104	26	13	10	18	<5	13	8.9	480	1200	960	240	87
Mean		67	7.9	2720	26.6	15	9.3	5.8	12	<5	13	3.8	360	813	673	176	69
Geo Mean		66	7.9	2530	18.9	13	8.0	5.4	12	<5	13	3.4	344	723	630	157	67
Median		65	8.0	2640	22.9	15	10.5	4.8	11	<5	13	3.3	370	855	675	210	74

Salt Slough at Lander Avenue (State Highway 165) (MER531)

Location: Latitude 37°14'55", Longitude 120°51'04". In NW 1/4, SE 1/4, SE 1/4, Sec. 10, T.8S., R.10E. 13.0 miles north of Los Banos. 5.0 miles south of Highway 140.

Date	Time	Temp °F	pH	EC umhos/cm	Se	Mo	Cr	Cu	Ni	Pb	Zn	B	Cl	SO4	HDNS	Ca	Mg
					ug/L							mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
10/2/97	1057	75	8.1	1020	1.6							0.50					
10/9/97	0925	63	7.6	1160	0.8							0.63					
10/16/97	1045	69	7.9	1380	1.0							0.74					
10/24/97	0725	60	7.2	1360	0.7							0.65					
10/30/97	1015	62	8.0	1390	0.7	7	2.8	3.5	<5	<5	9.8	0.62	230	180	270	NA	NA
11/6/97	0910	63	7.5	1450	0.8							0.71					
11/14/97	1205	59	7.7	1320	0.8							0.77					
11/19/97	1900	62	7.8	1510	1.9							0.82					
11/25/97	1050	64	7.4	1960	0.5	9						1.1					
12/5/97	1115	56	7.1	1940	0.8							1.3					
12/11/97	1055	48	7.8	2060	0.7							1.5					
12/18/97	1250	54	7.4	2260	1.3							1.4					
12/26/97	0915	46	7.8	2470	2.0	13						1.3					
1/2/98	1120	56	7.6	2730	0.7							1.4					
1/8/98	1205	56	8.0	2650	0.7							1.4					
1/15/98	1150	54	7.2	2370	1.6							1.4					
1/22/98	1035	52	7.8	2320	1.0							1.8					
1/29/98	0720	56	7.6	2180	0.9	13	2.5	2.9	6.3	<5	NA	1.8	350	390	470	97	56
2/5/98	1045	55	7.4	1370	2.2							1.3					
2/11/98	1205	54	7.4	1750	4.3							1.5					
2/19/98	1115	54	7.5	1990	4.5							1.7					
2/26/98	1050	59	7.5	2000	5.1	12						1.9					
3/5/98	1150	56	7.6	1970	2.2							1.6					
3/12/98	1040	62	7.4	1730	2.8							1.2					
3/19/98	1645	72	7.3	1840	1.6							1.3					
3/26/98	1010	64	7.2	1280	1.1							0.93					
4/2/98	1005	58	7.4	2050	1.4							1.4					
4/9/98	1105	63	7.7	2100	1.4							1.7					
4/16/98	0845	61	7.5	1950	1.4							1.5					
4/23/98	0850	72	7.5	1730	1.0							1.1					
4/30/98	0820	70	7.2	1410	0.8	7						0.92					
5/7/98	0940	66	7.3	1060	1.0							0.57					
5/14/98	0810	60	7.7	888	0.9	3	6.9	6.5	10	<5	NA	0.41	120	120	210	47	22
5/21/98	0730	65	7.6	1560	0.8							0.66					
5/28/98	1237	62	7.4	1040	0.7							0.45					
6/4/98	0900	68	7.6	1020	0.7							0.46					
6/11/98	1230	69	7.4	833	0.5							0.35					
6/18/98	0835	74	7.2	851	0.5							0.36					
6/25/98	1037	67	7.4	634	0.6	NA	4.2	4.7	7.3	<5	NA	0.26	82	74	150	35	15
7/2/98	0800	74	7.4	621	0.5							0.29					
7/9/98	1110	82	7.3	790	0.4							0.29					
7/16/98	1030	81	7.6	557	0.5							0.21					
7/23/98	1055	80	7.5	778	0.9							0.32					
7/30/98	1115	79	7.4	629	1.4							0.25					
8/6/98	0930	84	7.6	846	1.4							0.39					
8/12/98	1700	84	7.7	727	1.0							0.37					
8/20/98	1210	74	7.7	721	0.9							0.35					
8/27/98	1040	74	7.4	887	0.9	3						0.45					
9/3/98	0725	79	7.5	861	1.1							0.42					
9/10/98	0910	79	7.6	888	1.0							0.48					
9/17/98	1005	76	7.5	993	0.4							0.45					
9/24/98	0920	68	NA	993	0.8							0.45					
Count		52	51	52	52	8	4	4	4	4	1	52	4	4	4	3	3
Min		46	7.1	557	0.4	3	2.5	2.9	<5	<5	9.8	0.21	82	74	150	35	15
Max		84	8.1	2730	5.1	13	6.9	6.5	10	<5	9.8	1.9	350	390	470	97	56
Mean		65	7.5	1440	1.2	8	4.1	4.4	6.5	2.5	9.8	0.89	196	191	275	60	31
Geo Mean		65	7.5	1310	1.0	7	3.8	4.2	5.8	2.5	9.8	0.73	168	158	251	54	26
Median		64	7.5	1380	0.9	8	3.5	4.1	6.8	2.5	9.8	0.73	175	150	240	47	22

Mud Slough Upstream of San Luis Drain (MER536)

Location: Latitude 37°19'50", Longitude 120°57"03". In NW 1/4, NE 1/4, NW 1/4, Sec. 14, T.7S., R.9E. 5.0 miles east of Gustine, 3.5 miles SE of Highway 140. Located within Kesterson N. W. R.

Date	Time	Temp °F	pH	EC umhos/cm	Se	Mo	Cr	Cu	Ni	Pb	Zn	B	Cl	SO4	HDNS	Ca	Mg
					ug/L							mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
10/2/97	1244	75	8.0	891	0.7							0.72					
10/9/97	1025	65	8.0	998	0.7							0.82					
10/16/97	1245	72	7.9	866	0.7							0.78					
10/24/97	0820	60	7.9	1160	0.5							0.90					
10/30/97	0815	60	6.6	1340	0.5	7	3.1	14	7.7	<5	18	0.96	160	170	260	NA	NA
11/6/97	1025	66	8.0	1400	<0.4							1.2					
11/14/97	1440	62	7.8	1200	0.5							0.93					
11/19/97	2015	60	8.1	1300	0.7							1.0					
11/25/97	1310	66	7.8	1480	0.6	6						1.1					
12/5/97	1200	55	8.6	1430	0.8							1.2					
12/11/97	1130	49	7.9	1420	0.4							1.2					
12/18/97	1420	54	7.8	1640	0.5							1.4					
12/26/97	1150	46	7.6	1850	0.5	9						1.6					
1/2/98	1235	55	7.6	2210	0.4							1.9					
1/8/98	1410	54	8.2	2070	<0.4							1.7					
1/15/98	1355	54	7.3	1430	0.8							1.3					
1/22/98	1130	52	8.1	934	0.5							0.83					
1/29/98	0840	57	7.7	1420	0.6	4	10	6.8	17	<5	NA	1.3	170	200	300	53	40
2/5/98	0945	54	7.8	753	0.7							0.67					
2/11/98	NA	NA	NA	NA	NA							NA					
2/19/98	1200	56	7.7	823	1.0							0.79					
2/26/98	0815	57	7.8	838	1.1	3						0.89					
3/5/98	1325	55	7.9	1090	1.1							1.1					
3/12/98	1245	63	8.2	1490	1.3							1.4					
3/19/98	1735	72	8.5	1850	1.2							1.9					
3/26/98	1220	64	7.8	1430	1.3	3						1.5					
4/2/98	1110	58	8.0	1270	1.0							1.2					
4/9/98	1040	62	8.3	1330	1.3							1.3					
4/16/98	0710	57	8.4	1940	0.9							1.9					
4/23/98	1220	71	8.2	2330	1.1							2.4					
4/30/98	0940	75	7.8	3170	0.8	17						3.3					
5/7/98	1200	68	8.0	1110	1.7							1.2					
5/14/98	1000	61	7.2	1540	1.4	7	15	8.5	22	<5	NA	1.6	190	320	310	59	39
5/21/98	1045	67	8.4	1900	1.3							2.0					
5/28/98	1349	61	7.6	2800	1.0	18						3.1					
6/4/98	1125	74	8.3	1210	1.4							1.3					
6/11/98	1330	70	8.0	841	1.2							1.0					
6/18/98	1040	78	7.3	807	1.1							0.88					
6/25/98	1235	82	8.1	1010	1.4	4	9	4.8	13	<5	NA	1.1	120	200	220	42	28
7/2/98	1035	76	7.7	867	1.2							1.1					
7/9/98	1230	86	7.8	830	1.2							1.0					
7/16/98	1210	85	8.9	1060	1.5							1.1					
7/23/98	1245	84	7.9	947	1.8							1.1					
7/30/98	1140	83	7.9	1010	1.8	5						1.3					
8/6/98	1220	86	8.0	1080	1.6							1.1					
8/12/98	1350	91	8.2	1370	1.7							1.4					
8/20/98	1240	76	7.8	936	1.8							1.0					
8/27/98	1115	78	7.7	1030	1.4	5						1.1					
9/3/98	0950	81	7.8	730	1.9							0.73					
9/10/98	1105	71	7.7	595	0.9							0.47					
9/17/98	1055	76	7.4	618	1.0							0.50					
9/24/98	1210	73	NA	672	0.5	5						0.57					
Count		51	50	51	51	13	4	4	4	4	1	51	4	4	4	3	3
Min		46	6.6	595	<0.4	3	3.1	4.8	7.7	<5	18	0.47	120	170	220	42	28
Max		91	8.9	3170	1.9	18	15	14	22	<5	18	3.3	190	320	310	59	40
Mean		67	7.9	1300	1.0	7	9.3	8.5	15	<5	18	1.3	160	223	273	51	36
Geo Mean		66	7.9	1210	0.9	6	8.0	7.9	14	<5	18	1.2	158	216	270	51	35
Median		66	7.9	1200	1.0	5	9.5	7.7	15	<5	18	1.1	165	200	280	53	39

Inflow at San Luis Drain: check 17 (MER562)

Location: Latitude: 36°57.980', Longitude 120°40.238'. In Sec. 21, T.11S., R.12E. Just west of South Dos Palos Slightly downstream of point where the Grasslands Bypass empties into the San Luis Drain.

Date	Time	Temp °F	pH	EC umhos/cm	Se ug/L	Diss Se ug/L	Mo ug/L	B mg/L	Cl mg/L	SO4 mg/L	HDNS mg/L	Ca mg/L	Mg mg/L	TSS mg/L
10/1/97	1100	NA	NA	4440	83.6	80.5		6.1						NA
10/8/97	1145	NA	NA	4190	55.8	55.6		7.7						89
10/15/97	1140	NA	NA	5370	48.1	47.3		9.1						34
10/22/97	1030	NA	NA	5520	74.8	75.1		9.1						12
10/29/97	NA	NA	NA	5300	75.6	78.2		9.1						70
11/5/97	1120	NA	NA	4920	79.5	77.2		8.3						77
11/12/97	1140	NA	NA	4300	68.8	69.2		6.6						62
11/19/97	1120	NA	NA	5070	75.4	74.6		9.2						74
11/25/97	0915	NA	NA	4380	39.4	38.8		7.4						130
12/3/97	1240	NA	NA	4470	54.2	54.5		7.7						61
12/10/97	1015	NA	NA	4630	59.3	57.2		8.0						28
12/17/97	1130	NA	NA	5520	60.6	64.3		9.4						NA
12/23/97	1110	NA	NA	5800	87.1	84.2		10						NA
12/30/97	0940	NA	NA	6190	92.5	91.7		11						45
1/7/98	1245	NA	NA	5840	118	118		9.2						42
1/14/98	1130	NA	NA	4110	68.6	67.9		6.6						NA
1/21/98	1400	NA	NA	5800	82.5	81.7		9.9						67
1/28/98	1115	NA	NA	6100	78.2	77.4	34	11	770	2100	1500	390	120	79
2/4/98	1230	NA	NA	2040	19.2	18.4		3.3						260
2/11/98	1130	NA	NA	3450	47.4	45.9		4.8						NA
2/18/98	1300	NA	NA	3880	61.2	58.4		5.9						240
2/25/98	1115	NA	NA	3420	53.4	50.8		5.2						230
3/4/98	1130	NA	NA	5120	79.0	76.8		8.3						180
3/11/98	1130	NA	NA	5180	86.2	85.6		8.8						180
3/18/98	1115	NA	NA	5400	92.4	91.5		8.5						340
3/25/98	1130	NA	NA	3030	49.0	50.6		4.5						460
4/1/98	1100	NA	NA	NA	95.6	92.6		8.7						230
4/8/98	1230	NA	NA	4980	81.1	77.7		7.9						170
4/15/98	1145	NA	NA	5770	129	130		8.1						170
4/22/98	1145	NA	NA	6230	133	126		9.0						150
4/29/98	1140	NA	NA	5470	106	105		7.9						249
5/6/98	1055	NA	NA	5280	93.4	92.4		7.7						320
5/13/98	1240	NA	NA	3740	62.8	60.7		5.8						1100*
5/20/98	1130	NA	NA	5930	120	120		9.0						320
5/27/98	1120	NA	NA	5490	114	112		9.4						170
6/3/98	1235	NA	NA	6000	92.9	92.8		9.6						62
6/10/98	1130	NA	NA	5370	103	101		8.1						150
6/17/98	1130	NA	NA	4880	84.2	81.8		7.7						140
6/24/98	1130	NA	NA	4420	51.2	49.2		7.2						140
7/1/98	1130	NA	NA	4630	52.8	50.5		7.6						140
7/8/98	1105	NA	NA	4240	47.0	46.1		7.0						220
7/15/98	1110	NA	NA	4180	47.2	44.0		6.6						280
7/22/98	1115	NA	NA	4630	46.1	44.1		8.1						110
7/29/98	1300	NA	NA	4440	51.6	51.4		7.3						104
8/5/98	1120	NA	NA	4440	52.6	51.6		7.5						81
8/12/98	1110	NA	NA	4160	44.2	42.6		7.4						160
8/19/98	1215	NA	NA	3780	32.6	33.1		6.6						150
8/26/98	1250	NA	NA	4760	57.5	57.4	22	8.2						41
9/2/98	1235	NA	NA	4400	50.1	49.4		7.4						26
9/9/98	1241	NA	NA	3930	54.4	51.9		7.6						46
9/16/98	1015	NA	NA	3780	46.3	47.2		6.1						50
9/23/98	1120	NA	NA	3040	25.4	22.2		5.9						39
9/30/98	1240	NA	NA	4510	67.4	65.2		6.3						17
*Data suspected to be erroneous														
Count				52	53	53	2	53	1	1	1	1	1	47
Min				2040	19.2	18.4	22	3.3	770	2100	1500	390	120	12
Max				6230	133	130	34	11	770	2100	1500	390	120	460
Mean				4730	70.4	69	28	7.7	770	2100	1500	390	120	138
Geo Mean				4634	65.5	64	27	7.6	770	2100	1500	390	120	103
Median				4630	67.4	65	28	7.7	770	2100	1500	390	120	130

San Luis Drain @ Terminus (MER535)

Location: Latitude 37°19'50", Longitude 120°57"03" NW 1/4, NE 1/4, NW 1/4, Sec. 14, T.7S., R.9E. 5.0 miles east of Gustine, 3.5 miles SE of Highway 140. Located within Kesterson N.W.R.

Date	Time	Temp °F	pH	EC umhos/cm	Se ug/L	Diss Se ug/L	Mo ug/L	Cr ug/L	Cu ug/L	Ni ug/L	Pb ug/L	Zn ug/L	B mg/L	Cl mg/L	SO4 mg/L	HDNS mg/L	Ca mg/L	Mg mg/L	TSS mg/L
10/2/97	1150	78	8.1	4760	46.6	45.1							7.5						NA
10/9/97	0945	64	7.7	4610	52.2	52.6							8.5						26
10/16/97	1120	72	8.1	5290	51.6	51.6							9.1						32
10/24/97	0750	62	7.5	5040	60.8	60.2							8.2						13
10/30/97	0935	62	7.7	4970	61.0	60.9	44	3.8	4.1	6	<5	6.1	8.4	600	1700	1200	NA	NA	25
11/6/97	0930	67	8.2	5130	50.3	50.5							9.2						28
11/14/97	1225	62	7.6	4460	41.6	43.3							7.6						11
11/19/97	1930	60	7.8	4680	51.0	50.2							7.8						NA
11/25/97	1120	66	7.7	5010	48.8	50.6	48						8.5						17
12/5/97	1150	56	8.1	4530	34.0	33.9							7.8						33
12/11/97	0950	50	7.4	4250	48.9	49.0							6.7						38
12/18/97	1330	55	7.6	4680	48.9	51.8							7.5						NA
12/26/97	1000	46	8.1	5040	56.8	56.8	38						8.7						17
1/2/98	1150	55	8.3	5360	73.0	73.0							8.8						28
1/8/98	1240	54	8.1	5300	80.1	80.1							9.6						11
1/15/98	1255	53	7.5	5080	98.9	100							8.5						34
1/22/98	1215	52	8.2	4760	73.5	73.2							7.4						17
1/29/98	0925	55	7.9	5300	74.4	75.4	36	7.9	3.2	5.1	<5	NA	8.5	670	1700	1300	340	110	28
2/5/98	0750	51	7.2	2950	35.5	33.4							4.7						110
2/11/98	1240	56	7.7	3030	37.0	36.6							4.4						NA
2/19/98	1235	56	7.9	3900	55.0	54.4							5.8						79
2/26/98	0915	56	7.9	3390	39.0	42.6	7						4.7						240
3/5/98	1230	56	8.1	5240	82.4	80.5							8.3						130
3/12/98	1105	63	7.9	5410	85.8	88.8							8.4						66
3/19/98	1705	72	8.0	5590	91.5	90.9							8.2						120
3/26/98	1040	67	7.9	4720	77.6	79.4	16						7.5						140
4/2/98	1155	59	7.9	5160	90.0	92.8							8.3						87
4/9/98	0928	62	8.3	5550	94.6	93.0							8.4						75
4/16/98	0745	57	8.1	5930	118	120							8.4						60
4/23/98	0950	72	8.2	6070	119	119							9.2						56
4/30/98	0900	74	8.1	5550	106	106	26						8.1						67
5/7/98	1005	68	8.1	5860	104	104							8.2						75
5/14/98	0855	62	8.0	5990	99.2	99.4	32	12	3.5	8.2	<5	NA	8.4	730	2000	1500	390	120	NA
5/21/98	0800	68	8.1	5970	116	119							9.3						120
5/28/98	1315	61	8.2	5610	120	120	23						9.9						64
6/4/98	0935	72	8.4	4850	80.6	80.6							7.7						44
6/11/98	1255	70	8.4	5180	102	98.4							7.9						46
6/18/98	0910	78	8.4	5090	92.8	91.0							7.7						32
6/25/98	1126	81	8.3	4680	65.6	68.9	25	7.7	3.9	5.7	<5	NA	7.5	560	1600	1100	280	92	46
7/2/98	0835	74	8.4	4560	54.4	56.5							7.3						47
7/9/98	1130	84	7.7	4300	44.4	44.2							7.2						51
7/16/98	1225	86	8.1	4140	45.1	43.6							6.8						NA
7/23/98	1145	83	8.0	4340	48.3	46.9							7.4						77
7/30/98	1215	82	8.2	4550	50.5	50.6	21						7.6						19
8/6/98	1125	88	8.2	4330	49.2	48.1							7.3						31
8/12/98	1130	88	7.4	4240	48.4	48.3							7.4						52
8/20/98	1315	76	8.0	4130	44.4	44.2							6.9						48
8/27/98	1205	78	7.8	4490	51.0	52.4	21						7.6						44
9/3/98	0800	81	7.3	4280	46.1	46.8							7.4						NA
9/10/98	1015	73	8.1	4180	43.5	42.5							7.2						11
9/12/98	1015	NA	NA	4220	53.8	NA							6.9						NA
9/17/98	1020	78	7.5	3800	48.2	48.4							6.3						NA
9/24/98	1035	73	8.0	3990	37.4	32.2	34						6.5						55
Count		52	52	53	53	52	13	4	4	4	4	1	53	4	4	4	3	3	44
Min		46	7.2	2950	34.0	32.2	7	3.8	3.2	5.1	<5	6.1	4.4	560	1600	1100	280	92	11
Max		88	8.4	6070	120	120	48	12	4.1	8.2	<5	6.1	9.9	730	2000	1500	390	120	240
Mean		67	7.9	4780	66.6	67.0	29	7.9	3.7	6.3	<5	6.1	7.7	640	1750	1275	337	107	56
Geo Mean		66	7.9	4730	62.3	62.5	26	7.3	3.7	6.1	<5	6.1	7.6	637	1744	1267	334	107	43
Median		67	8.0	4760	54.4	55.5	26	7.8	3.7	5.85	<5	6.1	7.7	635	1700	1250	340	110	46

APPENDIX B

Water Quality Data from Sigma Autosamplers:

Water Year 1998

San Luis Drain @ Terminus (MER535S)

Location: Latitude 37°19'50", Longitude 120°57"03". In NW 1/4, NE 1/4, NW 1/4, Sec. 1
5.0 miles east of Gustine, 3.5 miles SE of Highway 140. Located within Kestersc

AUTOSAMPLER DATA : 24 hour composite samples

Date	EC umhos/cm	Se ug/L	B mg/L
10/1/97	4510	44.4	6.6
10/2/97	4670	45.2	7.1
10/3/97	4650	36.4	7.9
10/4/97	4300	37.8	7.6
10/5/97	4620	67.9	7.2
10/6/97	4520	55.6	7.5
10/7/97	4970	64.9	7.7
10/8/97	4820	60.7	8.0
10/9/97	4660	52.7	7.9
10/10/97	4500	54.3	7.4
10/11/97	4390	55.6	7.2
10/12/97	4710	63.0	8.0
10/13/97	4390	52.4	7.3
10/14/97	4590	46.2	7.4
10/15/97	5100	45.0	8.3
10/16/97	5440	48.2	9.0
10/17/97	5560	55.7	9.0
10/18/97	5490	43.6	9.1
10/19/97	5370	39.2	9.3
10/20/97	5170	34.5	8.7
10/21/97	5270	42.2	8.7
10/22/97	5300	58.0	8.5
10/23/97	5280	64.6	8.6
10/24/97	5150	59.3	8.2
10/25/97	5080	56.4	8.1
10/26/97	5260	59.4	8.4
10/27/97	5330	52.6	8.7
10/28/97	5200	51.3	8.7
10/29/97	5160	57.0	8.7
10/30/97	5070	51.8	8.6
10/31/97	4500	50.0	7.7
11/1/97	4380	47.1	7.5
11/2/97	4430	49.4	7.4
11/3/97	4500	42.6	7.5
11/4/97	5060	56.4	8.5
11/5/97	5130	55.2	8.9
11/6/97	5060	48.6	8.9
11/7/97	5210	56.4	9.3
11/8/97	5120	55.9	9.1
11/9/97	4750	50.7	8.2
11/10/97	4550	43.1	7.9
11/11/97	4660	48.4	7.8
11/12/97	4730	49.9	7.9
11/13/97	4700	54.0	7.7
11/14/97	4630	46.0	7.6
11/15/97	4530	41.8	7.6
11/16/97	4290	49.9	6.6
11/17/97	4320	49.6	6.5
11/18/97	4430	52.1	7.0
11/19/97	4520	48.2	7.5
11/20/97	4700	50.8	7.9
11/21/97	4680	48.0	8.0
11/22/97	4770	48.1	8.2
11/23/97	4650	46.0	7.7
11/24/97	4780	43.2	8.2
11/25/97	4900	46.4	8.5
11/26/97	4730	46.2	8.2
11/27/97	4710	49.8	8.2
11/28/97	4830	47.8	8.3
11/29/97	4950	50.6	8.2
11/30/97	4740	43.4	7.9
12/1/97	4270	26.7	6.9
12/2/97	4390	23.7	7.3
12/3/97	4510	28.2	7.1
12/4/97	4450	24.7	7.0
12/5/97	4500	33.8	7.5
12/6/97	3750	27.0	5.4
12/7/97	4370	34.8	7.1
12/8/97	4810	71.4	7.7
12/9/97	4540	73.5	7.1
12/10/97	4000	52.0	5.9
12/11/97	4310	56.0	6.6
12/12/97	4360	48.2	7.2
12/13/97	4220	45.0	6.9
12/14/97	4380	47.6	7.2
12/15/97	4400	48.1	7.2
12/16/97	4380	46.2	7.3
12/17/97	4580	45.2	7.7
12/18/97	4710	52.0	8.0
12/19/97	4670	47.0	7.9
12/20/97	4560	41.7	7.6
12/21/97	4590	46.5	7.7
12/22/97	4730	48.7	8.0
12/23/97	5040	61.6	8.5
12/24/97	5200	68.8	8.8
12/25/97	5070	66.2	8.7
12/26/97	4860	59.6	8.5
12/27/97	4910	58.8	8.6
12/28/97	4920	61.4	8.7
12/29/97	5060	59.5	9.1
12/30/97	5260	52.4	9.4
12/31/97	5110	54.3	9.5
1/1/98	5240	65.6	9.3
1/2/98	5160	74.5	9.0
1/3/98	5010	68.0	9.0
1/4/98	5190	71.3	9.4
1/5/98	5380	80.2	9.7
1/6/98	5350	95.1	9.6
1/7/98	5260	83.6	9.5
1/8/98	5080	80.8	9.2
1/9/98	5080	79.9	10
1/10/98	5110	86.5	10
1/11/98	5240	115	11
1/12/98	5150	114	10
1/13/98	4920	103	9.0
1/14/98	4830	100	8.5
1/15/98	4770	100	8.4
1/16/98	4840	102	8.9

San Luis Drain @ Terminus (MER535S) continued

Date	EC umhos/cm	Se ug/L	B mg/L
1/17/98	5070	118	9.1
1/18/98	5180	112	9.5
1/19/98	4830	92.4	8.6
1/20/98	4320	65.8	7.1
1/21/98	4110	65.4	6.7
1/22/98	4360	73.0	7.3
1/23/98	4760	57.1	7.1
1/24/98	4950	60.0	7.4
1/25/98	5420	84.0	8.5
1/26/98	5560	82.8	8.9
1/27/98	5400	72.8	8.5
1/28/98	5330	69.7	8.2
1/29/98	5560	77.1	8.5
1/30/98	5680	94.4	8.7
1/31/98	5600	90.1	8.5
2/1/98	5660	92.1	8.4
2/2/98	5570	76.6	8.7
2/3/98	4420	59.5	6.6
2/4/98	4370	57.1	6.7
2/5/98	3420	37.0	4.9
2/6/98	2430	24.8	3.8
2/7/98	3170	37.2	4.8
2/8/98	3350	45.8	4.9
2/9/98	3320	44.8	5.0
2/10/98	2900	37.0	4.3
2/11/98	3000	35.0	4.6
2/12/98	3280	43.0	4.9
2/13/98	3390	50.7	5.0
2/14/98	3540	52.4	5.2
2/15/98	3540	52.2	5.1
2/16/98	3610	54.3	5.3
2/17/98	3150	45.4	4.7
2/18/98	3660	54.9	5.5
2/19/98	3830	56.0	5.9
2/20/98	3920	58.8	6.0
2/21/98	3800	56.9	5.8
2/22/98	3240	47.8	4.8
2/23/98	3640	61.4	5.3
2/24/98	3700	62.6	5.5
2/25/98	3870	59.6	5.9
2/26/98	3840	56.4	5.9
2/27/98	3500	54.2	5.6
2/28/98	3890	57.0	5.9
3/1/98	4000	64.1	6.7
3/2/98	4340	68.2	6.8
3/3/98	4480	71.2	7.8
3/4/98	4830	78.8	8.4
3/5/98	5050	82.2	8.6
3/6/98	5160	81.6	8.5
3/7/98	5160	75.2	8.7
3/8/98	5150	82.0	8.7
3/9/98	5210	86.2	8.1
3/10/98	5260	86.2	8.2
3/11/98	5110	84.4	8.0
3/12/98	5270	86.2	8.1
3/13/98	4900	76.8	8.4
3/14/98	4940	86.9	8.2
3/15/98	4960	84.6	8.3
3/16/98	3800	60.8	6.1
3/17/98	4920	78.8	8.2
3/18/98	5260	87.8	8.9
3/19/98	5220	89.0	8.9
3/20/98	5320	92.1	9.1
3/21/98	5140	87.1	8.6
3/22/98	5210	95.6	8.7
3/23/98	5220	98.3	8.4
3/24/98	5220	102	8.3
3/25/98	5110	90.8	8.4
3/26/98	4990	89.6	8.3
3/27/98	3850	60.0	5.9
3/28/98	4960	80.1	7.6
3/29/98	5440	86.2	8.3
3/30/98	5620	94.6	8.3
3/31/98	5680	96.0	8.4
4/1/98	5770	98.2	8.5
4/2/98	5570	91.8	8.4
4/3/98	5730	96.6	8.5
4/4/98	5840	97.8	8.7
4/5/98	5750	94.2	8.8
4/6/98	5310	87.8	7.8
4/7/98	4500	63.9	7.0
4/8/98	4830	67.6	7.7
4/9/98	5400	83.4	8.1
4/10/98	5230	82.6	8.4
4/11/98	5810	103	9.0
4/12/98	5840	104	9.2
4/13/98	5920	122	8.5
4/14/98	5880	125	8.3
4/15/98	5910	120	8.4
4/16/98	5890	122	8.5
4/17/98	5860	126	8.6
4/18/98	5890	119	8.4
4/19/98	5690	103	8.2
4/20/98	6170	123	9.1
4/21/98	6090	123	9.2
4/22/98	6110	124	9.0
4/23/98	6000	122	9.0
4/24/98	6300	134	9.1
4/25/98	5690	106	8.7
4/26/98			
4/27/98	5580	106	8.0
4/28/98	5610	104	8.0
4/29/98	5600	104	8.1
4/30/98	5540	103	8.0
5/1/98	5700	111	8.1
5/2/98	5860	110	8.3
5/3/98	5990	114	8.5
5/4/98	5780	98.2	8.1
5/5/98	5840	101	8.0
5/6/98	5650	98.0	7.7
5/7/98	5750	99.6	8.1
5/8/98	5310	95.2	7.9
5/9/98	5100	81.3	7.8
5/10/98	5090	82.0	7.8
5/11/98	5360	89.3	8.2
5/12/98	5680	95.2	8.9
5/13/98	5880	102	9.1

San Luis Drain @ Terminus (MER535S) continued

Date	EC umhos/cm	Se ug/L	B mg/L
5/14/98	5670	101	8.9
5/15/98	3730	63.9	6.0
5/16/98	3890	68.9	6.3
5/17/98	4940	92.8	8.2
5/18/98	5560	107	9.3
5/19/98	5840	114	9.5
5/20/98	5920	116	9.8
5/21/98	5960	117	10
5/22/98	6080	120	9.3
5/23/98	6020	118	9.3
5/24/98	6070	122	9.3
5/25/98	6150	125	9.5
5/26/98	6330	128	9.7
5/27/98	6080	117	9.5
5/28/98	6020	119	9.3
5/29/98	5970	116	9.2
5/30/98	5810	110	8.8
5/31/98	5600	107	8.4
6/1/98	5330	95.1	8.2
6/2/98	5490	96.6	8.6
6/3/98	5740	108	8.9
6/4/98	5100	84.0	8.0
6/5/98	5910	93.6	8.7
6/6/98	5950	95.1	8.7
6/7/98	6110	103	8.9
6/8/98	5830	92.9	8.5
6/9/98	5160	93.0	7.4
6/10/98	4830	86.2	7.5
6/11/98	5280	99.4	8.0
6/12/98	5470	106	8.1
6/13/98	5480	93.6	7.9
6/14/98	5570	87.3	8.0
6/15/98	5350	73.1	8.3
6/16/98	5580	92.4	8.2
6/17/98	5130	82.2	7.7
6/18/98	4920	86.4	7.7
6/19/98	5220	85.5	8.0
6/20/98	5240	87.4	8.0
6/21/98	4920	78.2	7.5
6/22/98	4820	64.0	7.7
6/23/98	4900	64.5	7.9
6/24/98	4970	69.0	8.0
6/25/98	4930	64.8	7.9
6/26/98	4910	61.2	8.0
6/27/98	4690	54.6	7.9
6/28/98	4650	54.6	7.7
6/29/98	4550	57.0	7.2
6/30/98	4520	53.6	7.2
7/1/98	4710	56.4	7.8
7/2/98	4610	52.2	7.8
7/3/98	4920	53.5	8.1
7/4/98	4650	52.0	7.5
7/5/98	4350	43.8	7.2
7/6/98	4650	49.7	7.7
7/7/98	4560	51.8	7.3
7/8/98	4380	46.8	7.4
7/9/98	4360	44.5	7.6
7/10/98	4410	47.9	7.8
7/11/98	4180	44.4	7.2
7/12/98	4070	42.9	7.0
7/13/98	4110	45.0	7.0
7/14/98	4170	45.4	7.0
7/15/98	4030	45.7	6.9
7/16/98	4190	43.2	7.1
7/17/98	4400	49.1	7.5
7/18/98	4480	54.5	7.6
7/19/98	4440	54.9	7.4
7/20/98	4330	52.4	7.5
7/21/98	4190	45.7	7.5
7/22/98	4300	48.6	7.7
7/23/98	4440	50.2	7.9
7/24/98	4520	52.6	8.4
7/25/98	4720	53.6	8.7
7/26/98	4600	54.4	8.2
7/27/98	4440	48.0	8.0
7/28/98	4410	53.2	8.0
7/29/98	4510	53.4	8.1
7/30/98	4460	49.7	8.0
7/31/98	4560	55.3	8.0
8/1/98	4550	54.8	8.2
8/2/98	4550	51.2	8.3
8/3/98	4440	51.6	7.9
8/4/98	4390	54.4	7.8
8/5/98	4370	54.8	7.6
8/6/98	4400	51.4	7.9
8/7/98	4350	51.2	7.7
8/8/98	4430	54.6	7.9
8/9/98	4270	47.4	7.5
8/10/98	4390	52.5	7.6
8/11/98	4320	48.4	7.6
8/12/98	4070	47.7	7.2
8/13/98	4180	42.4	7.5
8/14/98	4330	47.4	7.7
8/15/98	4200	39.8	7.5
8/16/98	4100	39.0	7.2
8/17/98	4140	36.8	7.3
8/18/98	4260	42.0	7.0
8/19/98	4150	42.3	6.7
8/20/98	4130	42.9	6.5
8/21/98	3800	37.7	6.0
8/22/98	3900	33.1	6.4
8/23/98	3930	36.7	6.4
8/24/98	4230	45.5	7.1
8/25/98	4520	50.5	7.6
8/26/98	4590	52.8	7.6
8/27/98	4550	53.5	7.7
8/28/98	4770	55.1	8.4
8/29/98	4650	51.2	8.3
8/30/98	4590	51.4	8.2
8/31/98	4440	51.2	7.7
9/1/98	4410	51.1	7.5
9/2/98	4330	50.6	1.4
9/3/98	4410	49.8	7.3
9/4/98	4480	51.4	7.7
9/5/98	4290	45.5	7.5
9/6/98	4080	43.9	7.1
9/7/98	4210	50.0	7.2
9/8/98	4300	46.6	7.3

San Luis Drain @ Terminus (MER535S) continued

Date	EC umhos/cm	Se ug/L	B mg/L
9/9/98	4290	44.6	7.2
9/10/98	4360	43.4	7.4
9/11/98	4510	58.5	7.6
9/13/98	4200	52.6	6.9
9/14/98	3970	53.0	6.5
9/15/98	4010	57.2	6.5
9/16/98	3900	57.6	6.4
9/17/98	3980	55.2	6.5
9/18/98	4140	64.9	6.7
9/19/98	3740	42.8	6.2
9/20/98	3560	37.4	5.9
9/21/98	3810	37.1	6.1
9/22/98	3819	34.3	6.1
9/23/98	3713	34.0	5.8
9/24/98	3620	31.2	5.6
9/25/98	3910	26.0	6.0
9/26/98	3510	20.2	5.6
9/27/98	3880	23.6	6.0
9/28/98	4180	26.1	6.4
9/29/98	3760	26.4	6.3
9/30/98	3430	24.2	5.4
Count	363	363	363
Min	2430	20.2	1.4
Max	6330	134	11
Mean	4790	66.9	7.8
Geo Mean	4730	62.2	7.6
Median	4730	56.4	7.9

Inflow to San Luis Drain (MER562S)

Location:

AUTOSAMPLER DATA : 24 hour composite samples

Date	EC umhos/cm	Date	EC umhos/cm	Date	EC umhos/cm	Date	EC umhos/cm
5/1/98	6250	6/9/98	4330	7/14/98	3660	9/1/98	3210
5/2/98	6480	6/10/98	5100	7/15/98	3750	9/2/98	3300
5/3/98	6610	6/10/98	5490	7/16/98	4120	9/3/98	4300
5/4/98	6510	6/11/98	4390	7/17/98	4240	9/4/98	4180
5/5/98	6390	6/12/98	5300	7/18/98	3920	9/5/98	
5/6/98	6180	6/13/98	5380	7/19/98	3840	9/6/98	
5/7/98	4940	6/14/98	5800	7/20/98		9/7/98	
5/8/98	5190	6/15/98	5560	7/21/98	3750	9/8/98	
5/9/98	5730	6/16/98	4850	7/22/98		9/9/98	4370
5/10/98	5970	6/17/98	4620	7/23/98	4270	9/10/98	4120
5/13/98	3650	6/18/98	4930	7/24/98		9/11/98	4300
5/14/98	4650	6/19/98	4340	7/25/98		9/12/98	3830
5/15/98		6/20/98	4400	7/26/98		9/13/98	3940
5/16/98	5430	6/21/98	4300	7/27/98		9/14/98	4210
5/17/98	5780	6/22/98	4390	7/28/98		9/15/98	4270
5/18/98	5890	6/23/98	4510	7/29/98		9/16/98	4130
5/19/98	5930	6/24/98	4510	8/12/98	4180	9/17/98	3840
5/20/98		6/25/98	4220	8/13/98	3600	9/18/98	3780
5/21/98	6260	6/26/98	4340	8/14/98	4900	9/19/98	4230
5/22/98	6230	6/27/98	4210	8/15/98	3980	9/20/98	4210
5/23/98	6160	6/28/98	4260	8/16/98	3750	9/21/98	3940
5/24/98	6400	6/29/98	4560	8/17/98	3940	9/22/98	4320
5/25/98	6310	6/30/98	4380	8/18/98	4030	9/24/98	3790
5/26/98	5710	7/1/98	4370	8/19/98	3960	9/25/98	4680
5/27/98	5870	7/2/98	4860	8/20/98	3680	9/26/98	4560
5/28/98	5280	7/3/98	4200	8/21/98	3880	9/27/98	3820
5/29/98	5650	7/4/98	4160	8/22/98	4270	9/28/98	3450
5/30/98	5750	7/5/98	4620	8/23/98	4640	9/29/98	3300
5/31/98	6030	7/6/98	4520	8/24/98	4610	9/30/98	3860
6/1/98	5840	7/7/98	4360	8/25/98	4550	**Count**	**122**
6/2/98		7/8/98	4260	8/26/98	4690	**Min**	**1040**
6/4/98	5230	7/9/98	4450	8/27/98	3730	**Max**	**6610**
6/5/98	5830	7/10/98	4310	8/28/98	1040	**Mean**	**4628**
6/6/98	6240	7/11/98	4120	8/29/98	3780	**Geo Mean**	**4515**
6/7/98	5880	7/12/98	3850	8/30/98	3980	**Median**	**4365**
6/8/98	5710	7/13/98	3890	8/31/98	1850		

Analyses done from weekly composites of above samples:

Date	EC umhos/cm	Se ug/L	B mg/L	Date	EC umhos/cm	Se ug/L	B mg/L
5/6/98	6080	110	NA	8/26/98	4380	44.6	7.3
5/12/98	5400	97.0	8.2	9/2/98	2800	43.2	NA
5/19/98	5280	98.0	NA	9/9/98	4220	52.4	7.9
5/26/98	5990	120	9.1	9/15/98	4170	51.0	7.0
6/2/98	5740	107	NA	9/22/98	4100	43.0	6.8
6/10/98	5490	97.8	8.1	9/30/98	3890	34.2	6.3
6/17/98	5120	89.2	7.6				
6/24/98	4520	66.6	6.6	**Count**	20	20	16
7/1/98	4410	49.8	7.4	**Min**	2800	34.2	6.3
7/8/98	4480	47.0	7.3	**Max**	6080	120	9.1
7/15/98	4110	44.0	6.7	**Mean**	4612	66.6	7.3
7/22/98	3950	50.5	6.9	**Geo Mean**	4538	61.4	7.3
8/12/98	4180	48.3	7.5	**Median**	4395	50.8	7.3
8/19/98	3930	38.6	6.5				